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EVALUATION OF CONTROL TECHNOLOGIES FOR HAZARDOUS AIR POLLUTANTS
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EVALUATION OF CONTROL TECHNOLOGIES FOR HAZARDOUS AIR POLLUTANTS

Volume 2. Appendices

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16. ABSTRACT The manual is an aid to EPA regional, state, and local air pollution control agency technical personnel in selecting, evaluating, and developing costs of air pollution control techniques for reducing or eliminating the emission of potentially hazardous air pollutants (HAPs) from industrial/commercial sources. It contains information that should be useful for reviewing permit applications or for informing interested parties as to the type, basic design, and cost of available HAP control systems. Since the definition of a HAP is very broad (encompasses potentially thousands of compounds), it is not possible for this handbook to include an all-inclusive list of HAP compounds and compound-specific control techniques. However, there are only a few available generic air pollution control techniques, and the factors affecting their cost and performance as applied to many noncriteria pollutants have been identified and discussed in the literature. Therefore, the main focus of this manual is to provide sufficient guidance to select the appropriate air pollution control system(s) for an emission stream/source containing HAPs. The manual will help the user: (1) select the aporopriate control technique for each HAP emission stream at each facility; (2) determine the basic design of the selected air pollution control device(s); and (3) estimate order-of-magnitude control system capital and annualized costs.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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Evaluation	Stationary Sources	14G
Toxicity	Hazardous Air Pollutants	06T
Cost Analysis		14A

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This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ABSTRACT

The purpose of this manual is to help EPA regional, State, and local air pollution control agency technical personnel to select, evaluate, and cost air pollution control techniques for reducing or eliminating the emission of potentially hazardous air pollutants (HAP's) from industrial/commercial sources. The information provided by this manual will be useful for reviewing permit applications or for informing interested parties as to the type, basic design, and cost of available HAP control systems.

Since the definition of a HAP is very broad and, thus, encompasses potentially thousands of specific compounds, it is not possible for this handbook to develop an all-inclusive list of HAP compounds and compound-specific control techniques. However, the number of generic air pollution control techniques available is small, and the factors affecting the cost and performance of these controls as applied to many noncriteria pollutants have been identified and discussed in the literature. Therefore, the main focus of this manual is to provide sufficient guidance to select the appropriate air pollution control system(s) for an emission stream/source containing HAP's.

The manual will help the user perform three distinct functions: (1) to select the appropriate control technique(s) that can be applied to each HAP emission stream generated at a specific facility, (2) to determine the basic design parameters of the selected air pollution control device(s) and accompanying auxiliary equipment, and (3) to estimate order-of-magnitude control system capital and annualized costs.

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NOMENCLATURE[a]

a = packing constant

A = heat exchanger surface area, ft^2

A_{bed} = carbon bed cross sectional area, ft^2

A_{column} = absorber column cross sectional area, ft^2

A_{con} = condenser surface area, ft^2

A_{nc} = net cloth area, ft^2

A_p = collection plate area, ft^2

A_t = venturi scrubber throat area, ft^2

A_{tc} = total cloth area, ft^2

ABS = abscissa (Figure 4.6-2)

AC = adsorption capacity of carbon bed, lb HAP/100 lb carbon

A/C = air to cloth ratio for baghouse, $acfm/ft^2$

AF = absorption factor

b = packing constant

c = packing constant

C = annual credits, \$/yr

C_{req} = amount of carbon required, lb

Cp_{air} = average specific heat of air, Btu/scf-^oF

$\bar{C}p_{air}$ = average specific heat of air, Btu/lb-mole-^oF

Cp_{com} = average specific heat of combined gas stream, Btu/scf-^oF

$\underline{C}p_{coolant}$ = average specific heat of coolant, Btu/lb-^oF

Cp_e = average specific heat of emission stream, Btu/scf-^oF

$\underline{C}p_e$ = average specific heat of emission stream, Btu/lb-^oF

$\underline{C}p_f$ = average specific heat of supplementary fuel (natural gas), Btu/lb-^oF

Cp_{fg} = average specific heat of flue gas, Btu/scf-^oF

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[a] English units are used throughout this report. Appendix B.1 provides conversion factors for English to Metric units.

$\underline{C}p_{flg}$ = average specific heat of flare gas, Btu/lb-^{o}F

$\underline{C}p_{w}$ = average specific heat of water, Btu/lb-^{o}F

$\bar{C}p_{HAP}$ = average specific heat of HAP, Btu/lb-mole-^{o}F

CE = collection efficiency (based on mass), percent

CRF = capital recovery factor

CRF_{w} = weighted average capital recovery factor

d = packing constant

D = annual direct labor costs, $/yr

D_{bed} = carbon bed diameter, ft

D_{column} = absorber column diameter, ft

D_{duct} = duct diameter, in.

D_{p} = mean particle diameter, m

D_{t} = venturi scrubber throat diameter, ft

D_{tip} = flare tip diameter, in.

D_{G} = diffusivity in gas stream, ft^{2}/hr

D_{L} = diffusivity in liquid, ft^{2}/hr

D_{1} = annual operating labor cost, $/yr

D_{2} = annual supervision labor cost, $/yr

DE = destruction efficiency, percent

$DE_{reported}$ = reported destruction efficiency, percent

DP = stream dew point, ^{o}F

ex = excess air, percent (volume)

f = fraction

FE = fabricated equipment cost index

FER = fan electricity requirement, kWh

g = packing constant

g_c = gravitational constant, = 32.2 ft/sec^2

G = gas (emission stream) flow rate, lb/hr

G_{area} = gas (emission stream) flow rate based on column cross sectional area, lb/sec-ft^2

$G_{area,f}$ = gas (emission stream) flow rate at flooding conditions based on column cross sectional area, lb/sec-ft^2

G_{mol} = gas (emission stream) flow rate, lb-mole/hr

h_d = heat content of emission stream after dilution, Btu/scf

h_e = heat content of emission stream, Btu/scf

h_f = lower heating value of supplementary fuel (natural gas), Btu/scf

h_{flg} = flare gas heat content, Btu/scf

ΔH = heat of vaporization of HAP, Btu/lb-mole

H_{con} = enthalpy change associated with condensed HAP, Btu/min

H_f = supplementary heat requirement (heat supplied by the supplementary fuel), Btu/min

H_{load} = condenser heat load, Btu/hr

H_{noncon} = enthalpy change associated with noncondensable vapors, Btu/min

H_{uncon} = enthalpy change associated with uncondensed HAP, Btu/min

H_G = height of a gas transfer unit, ft

H_L = height of a liquid transfer unit, ft

H_{OG} = height of a gas transfer unit (based on overall gas film coefficients), ft

Ht_{column} = absorber column packed height, ft

Ht_{total} = absorber column total height, ft

HAP_{con} = quantity of HAP condensed, lb-mole/min

HAP_e = inlet HAP concentration, ppmv

$HAP_{e,m}$ = quantity of HAP in the emission stream entering the condenser, lb-mole/min

HAP_o = outlet HAP concentration, ppmv

$HAP_{o,m}$ = quantity of HAP in the emission stream exiting the condenser, lb-mole/min

HP = fan power requirement, hp (horsepower)

HR = heat recovery in the heat exchanger, percent

HRS = number of hours of operation per year

L = solvent flow rate, lb/hr

L'' = solvent flow rate based on absorber column cross sectional area, $lb/hr\text{-}ft^2$

L_{gal} = solvent flow rate, gal/min

L_{mol} = solvent flow rate, lb-mole/hr

L_v = liquid flow rate in venturi scrubber, gal/min

$L_v/Q_{e,a}$ = liquid to gas ratio, $gal/10^3$ acf

LEL = lower explosive limit, percent (volume)

m = slope of the equilibrium curve

M = annual maintenance costs, $/yr

M_e = moisture content of emission stream, percent (volume)

M_1 = annual maintenance labor cost, $/yr

M_2 = annual maintenance supervision cost, $/yr

M_3 = annual maintenance materials cost, $/yr

MW_{avg} = average molecular weight of a mixture of components, lb/lb-mole

MW_e = average molecular weight of emission stream, lb/lb-mole

MW_{flg} = average molecular weight of flare gas, lb/lb-mole

$MW_{solvent}$ = molecular weight of solvent, lb/lb-mole

MW_{HAP} = molecular weight of HAP (average molecular weight if a mixture of HAPs is present), lb/lb-mole

N = number of carbon beds

N_{OG} = number of gas transfer units (based on overall gas film coefficients)

O_2 = oxygen content of emission stream, percent (volume)

ORD = ordinate (Figure 4.6-2)

ΔP = total pressure drop for the control system, in.H_2O

ΔP_a = absorber column pressure drop, lb/ft^2-ft

P_e = emission stream pressure, mm Hg

$P_{partial}$ = partial pressure of HAP in emission stream, mm Hg

P_{vapor} = vapor pressure of HAP in emission stream, mm Hg

ΔP_{total} = absorber column total pressure drop, in.H_2O

ΔP_v = pressure drop across venturi, in.H_2O

PC = purchased equipment cost, $

Q_a = flow rate of gas stream at actual conditions, acfm

Q_c = combustion air flow rate, scfm

Q_{com} = flow rate of combined gas stream entering the catalyst bed, scfm

$Q_{coolant}$ = coolant flow rate, lb/hr

$Q_{cool,w}$ = cooling water flow rate, lb/min

Q_e = emission stream flow rate, scfm

$Q_{e,s}$ = saturated emission stream flow rate, acfm

Q_f = supplementary fuel (natural gas) flow rate, scfm

Q_{fg} = flue gas flow rate, scfm

$Q_{fg,a}$ = flue gas flow rate at actual conditions, acfm

Q_{flg} = flare gas flow rate, scfm

$Q_{flg,a}$ = flare gas flow rate at actual conditions, acfm

Q_{rec} = quantity of HAP recovered, lb/hr

Q_s = steam flow rate, lb/min

Q_w = cooling water flow rate, gal/min

r = packing constant

R = gas constant, = 0.73 ft^3-atm/lb-mole ^oR; = 1.987 cal/g-mole ^oK

R_{hum} = relative humidity, percent

Ref = refrigeration capacity, tons

RE = removal efficiency, percent

$RE_{reported}$ = reported removal efficiency, percent

s = packing constant

S = annual cost of operating supplies, \$/yr

Sc_G = Schmidt number for HAP/emission stream

Sc_L = Schmidt number for HAP/solvent system

St = steam ratio, lb steam/lb carbon

SV = space velocity, hr^{-1}

t_c = cleaning interval, min

t_r = residence time, sec

T = temperature, ^oF

T_c = combustion temperature, ^oF

T_{ci} = temperature of combined gas stream entering the catalyst bed, ^oF

T_{co} = temperature of flue gas leaving the catalyst bed, ^oF

T_{con} = condensation temperature, ^oF

$T_{cool,i}$ = inlet temperature of coolant, ^oF

$T_{cool,o}$ = outlet temperature of coolant, ^oF

T_e = emission stream temperature, ^oF

$T_{e,s}$ = temperature of saturated emission stream, ^oF

T_{flg} = flare gas temperature, ^oF

T_{he} = emission stream temperature after heat exchanger, ^oF

T_r = reference temperature, = 70^oF

T_{sti} = inlet steam temperature, ^oF

T_{sto} = condensed steam outlet temperature, ^{o}F

T_{wi} = inlet cooling water temperature, ^{o}F

T_{wo} = outlet cooling water temperature, ^{o}F

ΔT_{LM} = logarithmic mean temperature difference, ^{o}F

Th_{column} = absorber column thickness, ft

U = overall heat transfer coefficient, Btu/hr-ft^{2}-^{o}F

U_{d} = drift velocity of particles, ft/sec

U_{duct} = velocity of gas stream in the duct, ft/min

U_{e} = emission stream velocity through carbon bed, ft/min

$U_{e,s}$ = throat velocity of saturated emission stream, ft/sec

U_{flg} = flare gas exit velocity, ft/sec

U_{max} = maximum flare gas velocity, ft/sec

Ut = annual utility costs, \$/yr

V_{c} = combustion chamber volume, ft^{3}

V_{carbon} = volume of carbon bed, ft^{3}

V_{bed} = catalyst bed requirement, ft^{3}

$V_{packing}$ = absorber column packing volume, ft^{3}

W = particle grain loading, gr/acf

Wt_{column} = absorber column weight, lb

$\bar{x}$ = mole fraction of solute in solvent, moles solute/(moles solute + moles solvent)

$\bar{X}$ = mole fraction of gaseous component in liquid, moles solute/ moles solvent

$\bar{y}$ = mole fraction of solute in air, moles solute/(moles solute + moles air)

Y = packing constant

$\bar{Y}$ = mole fraction of solute in air, moles solute/moles air

Z_{bed} = carbon bed depth, ft

ϵ = packing constant

λ = latent heat of vaporization for steam, Btu/lb

η = fan efficiency, percent

ρ_{bed} = density of carbon bed, lb/ft^3

ρ_C = density of carbon steel plate, lb/ft^3

ρ_G = density of gas (emission stream), lb/ft^3

ρ_L = density of solvent, lb/ft^3

θ_{ads} = cycle time for adsorption, hr

θ_{reg} = cycle time for regeneration, hr

μ_L = viscosity of solvent, centipoise

μ_L'' = viscosity of solvent, lb/ft-hr

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APPENDIX A.1

NEW YORK STATE AIR GUIDE - 1

Guidelines for the Control of Hazardous Ambient Air Contaminants

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New York State Department of Environmental Conservation
50 Wolf Road, Albany, New York 12233-0001

Henry G. Williams
Commissioner

AIR GUIDE-1

INTRODUCTION

Air Guide-1 is the combined effort of the DEC Bureau of Air Toxics (BAT) and the DEC Bureau of Impact Assessment and Meteorology (BIAM), with the NYS DOH Bureau of Toxic Substance Assessment concurrence for the Appendix B methods.

Appendix A: Screening Analysis for Ambient Air Quality Impact

The derivation of the method is contained in the paper "Screening Procedures for Determining Ambient Impacts of Toxic Contaminants" by Leon Sedefian, DEC BIAM. This work describes the assumptions and qualifications of the procedures. Section II of Appendix A briefly outlines these assumptions and qualifications and should be reviewed prior to using the stepwise procedures.

Appendix B: Toxicity Classification

Dr. Moises Riano, DEC Bureau of Air Toxics Assessment Section, based the Toxicity Classifications on the following compound characteristics: Oral and Inhalation Toxicity, Carcinogenicity, Mutagenicity, Teratogenicity, Reproductive (embryotoxicity) Effects, and the Degree of Irritation. References from IARC, OSHA, NIOSH, NTP, and NCI, as well as other scientific data bases are evaluated in classifying contaminants.

These appendices follow a short text, dedicated to the regulatory implementation of Air Guide-1. Questions regarding this text, and Air Guide-1 implementation in general, should be directed to the staff of the Toxics Management Section in Bureau of Air Toxics, (518)457-7454. Primary contacts in this section are Ed Anna and Stan Byer.

GUIDELINES FOR THE CONTROL OF TOXIC AIR CONTAMINANTS

This guideline supersedes Chapters 3900 and 4100 of the Process Source Handbook and the 12/15/83 version of Air Guide-1.

This guideline is a screening mechanism to determine whether permits should be issued. The Regional Air Pollution Control Engineer (RAPCE) should use the following procedure as a guideline for Acceptable Ambient Levels (AAL's), and for applying control requirements in the review of applications and permits issued under 6 NYCRR Part 212. Failure to meet an AAL on a screening basis does not necessarily mean that a permit should be denied.

In addition to reviewing control requirements under 6NYCRR Part 212, the Air Guide-1 screening methods may be used to assess other air contaminant sources which may cause contravention of ambient air quality standards and/or cause air pollution. This is in accordance with the concern for ambient air quality as expressed in 6NYCRR Parts 200 and 257. In such cases where contravention occurs, or may occur, the commissioner may specify the degree and/or method of emission control required.

It is DEC's intention to list in AG-1 an AAL guideline value specifically developed for each chemical. Contaminant specific AAL's are determined by DEC and DOH toxicologists after analysis of all available data, using risk assessment technology suitable for the contaminant. These values are identified by a (DEC) or (DOH) in the tables.

Given the vast numbers of chemicals in use in NYS, the toxicity data available, and the lengthy process involved in developing each contaminant specific AAL, only a portion of the chemicals listed in AG-1 have contaminant specific AAL's. For the remaining chemicals, interim AAL values - identified by (T) - are derived from the American Conference of Industrial Governmental Hygienists' (ACGIH) Threshold Limit Value-Time Weighted Averages (TWA-TLV, or TLV). This is done even though the ACGIH TLV booklet states: "They (TLV's) are not intended for use, or modification for use, (1) as a relative index of hazard or toxicity, (2) in the evaluation or control of community air pollution nuisances, (3) in estimating the toxic potential of continuous, uninterrupted exposures.." It further states, "The TLV-TWAs should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations."

Notwithstanding these ACGIH caveats, the TLV values are the most complete listing of quantified acceptable exposure levels available, and are thus considered by DEC to be a valuable tool. To address the concern about using TLV's for non-occupational exposures, DEC and DOH scientists have categorized chemicals into high, moderate, or low toxicity classifications which are defined in Appendix B. These categories are based on the type of chronic and/or acute toxic effect of each chemical of concern. The safety factors used with the TLV's to calculate AAL's are a function of the chemicals's toxicity classification.

The ACGIH concern that TLV's "not be used as fine lines between safe and dangerous concentrations" is addressed by the screening guideline nature of the Air Guide-1 document. The Acceptable Ambient Levels (AAL's) given are guideline values - not standards. Also, the meteorologic impact calculations of Appendix A, while conservative in nature, are mathematical estimates only, a factor contributing to the guideline status of the Air Guide-1 methodologies.

I. High Toxicity Air Contaminants

A. High Toxicity air contaminants are demonstrated or potential human carcinogens, and other substances posing a significant health risk to humans. When reviewing sources which emit High Toxicity contaminants, the following guidelines must be considered:

(1) The maximum annual average ambient concentration should not exceed the AAL as defined in paragraph (B) and;

(2) BACT (best available control technology) should be applied to sources emitting High Toxicity Air Contaminants as outlined in paragraph (C).

B. For any High Toxicity air contaminant that has (1) an applicable National or State Ambient Air Quality Standard (Table 1), or (2) specific National Emission Standards for Hazardous Air Pollutants (NESHAPS), (Table 1A), the applicable standard shall be used by the RAPCE. The ambient air quality impact should be verified as acceptable in relation to these standards, or applicable AAL, for any High Toxicity Air Contaminant.

An AAL is the contaminant concentration which is considered to be an acceptable average concentration at a receptor on an annual basis. These values are developed as guidelines to safeguard receptors against potential chronic effects resulting from continuing exposures.

Chemicals classified High Toxicity by DEC and/or DOH toxicologists have AAL's listed in Table II. Chemicals for which a complete toxicity analysis has been done have contaminant specfic AAL's listed. These are identified by a (DEC) or (DOH) after the value in the Table. For chemicals not yet evaluated, an interim AAL (denoted by (T) in Table II), is determined by multiplying the current American Conference of Governmental Industrial Hygienists (ACGIH) time weighted average threshold level value (TWA-TLV) for the contaminant by the factor (1/300). If there is no current TWA-TLV, or if the standard or AAL is not met when BACT is applied, the RAPCE should consult with the Toxics Management Section for further guidance as indicated in Figure 1, Decision Process.

C. Any chemical designated as a High Toxicity air contaminant (Table II) by the New York State Department of Environmental Conservation (DEC), and the Department of Health (DOH), and not otherwise regulated for specific processes under 40 CFR 61, the National Emission Standards for Hazardous Air Pollutants (NESHAPS), or 40 CFR 761, the Toxic Substance Control Act (TSCA) must be assigned an "A" environmental rating and BACT shall be required for the source. The RAPCE is advised to consult with the Bureau of Source Control for further guidance in those cases where BACT results in less than 99% control.

D. If the emission rate potential (ERP) for any High Toxicity air contaminant is less than 1.0 lb/hr (without air cleaning), the RAPCE has an option of waiving BACT and setting other control requirements (including no control) provided the impact calculated from the source's actual emission rate yields a predicted ambient concentration at any off-site receptor which does not exceed the applicable ambient standard or AAL. If the RAPCE determines that the standard or AAL will not be met, the procedure outlined in paragraphs A through C above should be followed.

E. The following special condition must be included on each Certificate to Operate for sources emitting High Toxicity contaminants: "Should significant new scientific evidence from a recognized institution result in a decision by DEC that lower ambient levels must be established, it may be necessary to reduce emissions from this source prior to the expiration of this Certificate to Operate".

II. Moderate and Low Toxicity Air Contaminants

A. When a National or State Ambient Air Quality Standard (Table 1), or chemical specific AAL approved by the Division of Air exists for Moderate or Low Toxicity air contaminants, it shall be used by the RAPCE.

B. Whenever an ambient standard or chemical specific AAL does not exist, the RAPCE should establish an appropriate environmental rating, in accordance with Part 212, which would specify a degree of control or emission level sufficient to yield a predicted ambient concentration at any off-site receptor not exceeding the derived AAL. This AAL is calculated according to the following guidelines:

(1) Moderate Toxicity air contaminants - These contaminants (Table III) are animal carcinogens, mutagens, teratogens or other substances posing a health risk to humans. (TWA-TLV)/300 is used to determine the AAL.

(2) Low Toxicity air contaminants - These contaminants (Table IV) are of primary concern as irritants and have not been confirmed as carcinogens, mutagens, or teratogens in animal tests. (TWA-TLV)/50 is used to determine the AAL.

C. Part 212 "D" Ratings should be given only when;

(1) The contaminant requires no control to meet an ambient standard or AAL, and

(2) The contaminant is a "Nuisance Particulate" or a "Simple Asphyxiant" as listed in the ACGIH TLV booklet, or a chemical with similar properties.

III. Guidance for All Contaminants

The RAPCE should contact the Toxics Management Section, in accordance with the Decision Process in Figure 1, when:

A. There is no TLV or AAL for a High Toxicity Contaminant, or

B. There is no TLV or AAL for Moderate or Low Toxicity Contaminants and the Calculated Ambient Contaminant Impact is greater than the "de minimus" guideline AAL of 0.03 μg/m^3*, or

C. The AAL is not met.

When no AAL, TLV, or Toxicity Classifcation is available, it is the source owner's responsibility to provide enough toxicity data to allow an adequate permit review. At times, the attainment of this data and the appropriate DEC Central Office toxics policy guidance may not conform to Uniform Procedures Act (UPA) deadlines. When this situation arises, the permit may be issued for one year, if:

1. The RAPCE is reasonably assured that the toxicity data needed for a complete review will be forthcoming.

2. The DEC Toxic Management Section has confirmed through a "quick review," by the DEC toxicologist that the chemical is not likely to be classified a "High Toxity Contaminant".

While these conditions should allow RAPCE's to meet UPA deadlines without unnecessarily denying air emission permits, they are not meant to replace the usual review procedure. They are intended to serve as interim actions until a complete review can be accomplished.

IV. Exceptions

A. There may be times when the above methods might result in an ambient concentration which would be greater than the odor threshold for a contaminant. In these instances, the RAPCE should determine if the potential for a significant nuisance exists. If this is the case, the lower odor threshold value should be employed.

B. When a RAPCE encounters a situation not covered by this guideline or requiring special conditions, the Toxics Management Section should be consulted.

C. Any substance emitted from a source which is subject to 40 CFR 61 (NESHAPS) will be controlled solely under this federal regulation. Table IA lists the contaminants so affected.

V. Basic Considerations and Comments

A. The AAL's listed in by this guideline are to be considered incremental concentrations above the non-industrial background levels which currently exist for the respective substances. The influences of multiple emission points at one facility and the additional contributions from other facilities in the vicinity (approximately three miles) should be included in this evaluation according to the guidelines of Appendix A.

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*This interim "de minimus" AAL is recommended as a screening criterion for Moderate and Low Toxicity contaminants without TWA-TLV's until a contaminant specific AAL is established for each chemical.

To determine background levels, ambient measurements can be made at reasonable distances from known sources. These background concentrations would include emissions which may occur from homes, other local non-industrial sources, from mobile sources, and from naturally occurring sources.

B. AAL's for toxic air contaminants are continually being developed by the Division of Air Resources, New York State Department of Environmental Conservation (DEC), and the Bureau of Toxic Substances Assessment, New York State Department of Health (DOH), on a case by case basis. Tables I, IA, II, III, and IV are updated annually.

C. As a general rule, control requirements for High Toxicity air contaminants will be more restrictive than those developed for Moderate and Low Toxicity air contaminants.

D. Best Available Control Technology (BACT) may not always be sufficient to meet the AAL. In these cases, the matter should be reviewed in detail with the Toxics Management Section as noted in I, B, page 3.

E. The AAL's referred to in this guideline are annual average ambient concentrations that should not be exceeded for any off-site receptor. CO and PC applications for emission points with any chemicals listed in AG-1 or in the ACGIH TLV booklet should be screened by the RAPCE by using the stepwise evaluation of toxic contaminants procedure found in Appendix A of this Guideline, "Ambient Air Quality Impact Screening Analysis". The RAPCE is advised to consult with the Bureau of Impact Analysis and Meteorology (BIAM) for guidance in applying Appendix A when questions on meteorology arise.

F. For a chemical which has an assigned ACGIH TWA-TLV but is not listed in Air Guide-1, an assumption should be made that the chemical is of Moderate Toxicity. The methodology of section II, page 4, should be used to evaluate its impact on receptors.

Exception: Chemicals listed in ACGIH TLV book's Appendix A "Carcinogens" may pose a potential risk to humans and may be classifiable as High Toxicity contaminants. The Toxic Management Section should be consulted for guidance for these chemicals.

G. When no TWA-TLV's exist, Chemical Specific AAL's will be developed case by case basis for;

(1) Chemicals which meet Appendix B's High Toxicity criteria, and

(2) Moderate and Low Toxicity contaminants whose impacts exceed the "de minimus" value of 0.03 $\mu g/m^3$.

These chemical specific AAL's will be developed by DOH or DEC toxicologists, with appropriate peer review, under the administrative aegis of the Bureau of Air Toxics.

H. Short Term Impact: The fifteen minute ambient average concentration for a contaminant should not exceed the TLV at an off-site receptor. Judgment should be used by the RAPCE in evaluating the degree that the concentration exceeds the TLV, frequency of occurrence, and receptor location when applying this guidance. Please note footnote in tables for ACGIH "C" listed contaminants.

I. The following sampling procedures are suggested for use by the RAPCE to assure consistency with the intent of this policy. The choice of monitoring methods depend on the magnitude of the source, potential exposure of receptor and frequency of emissions from the source.

(1) Monitoring by the source owner or his authorized agent.
  a. Stack testing and site specific air quality impact analyses (compliance)..
  b. Ambient sampling at off-site receptors.
  c. Combination of (a) and (b).

(2) Selected sampling by appropriate DEC staff.
  a. Stack testing (surveillance).
  b. Ambient sampling (short-term).

J. For purposes of 6NYCRR Part 201.6(j)1, carcinogenic contaminants consist of the Table II High Toxicity Contaminants and chemicals listed in Appendix A of the ACGIH TLV booklet.

If you have any questions, please communicate directly with:

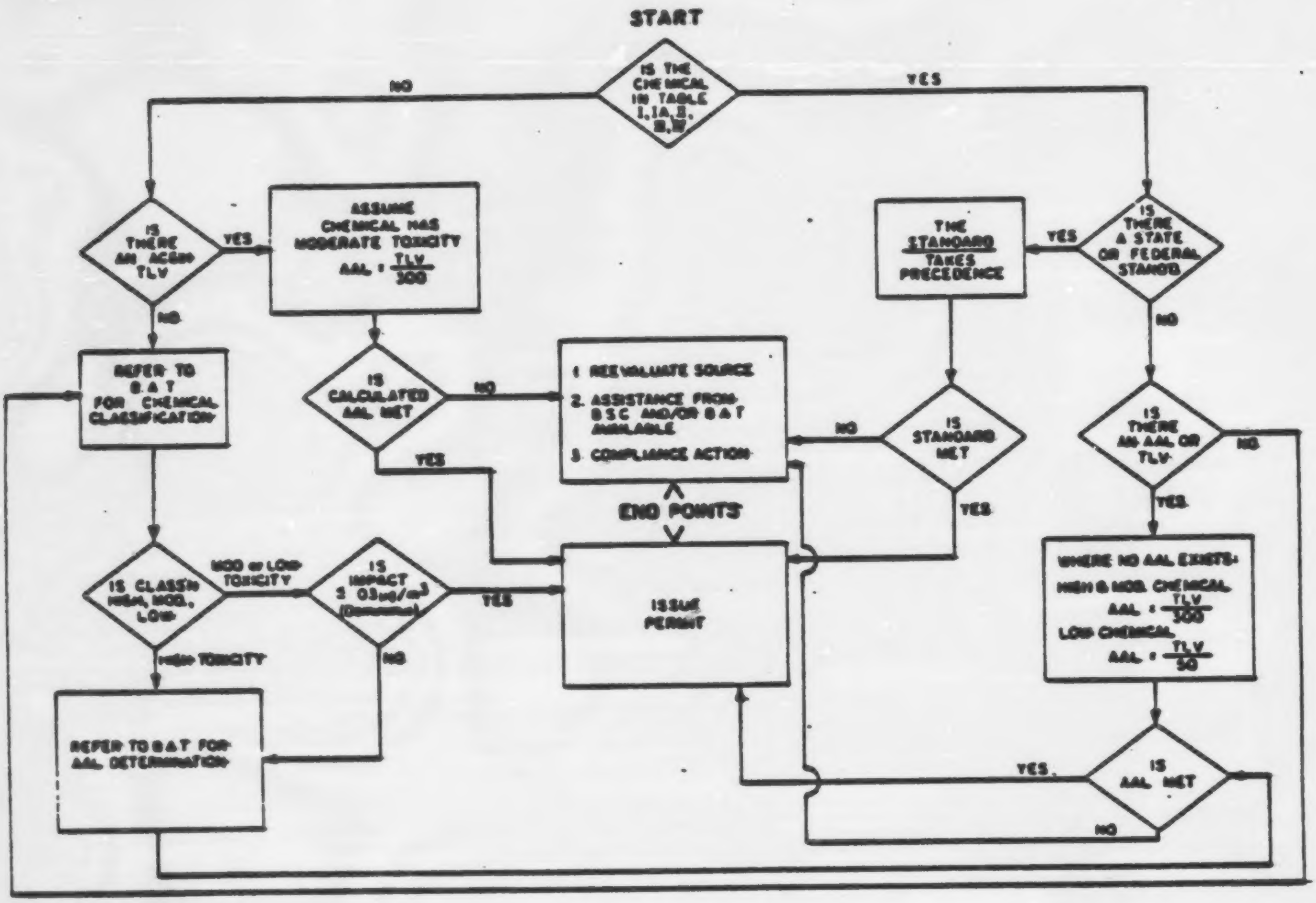
Mr. Edward Anna   Bureau of Air Toxics, Toxics Management Section,
Mr. Stanley Byer   (518) 457-7454

APPROVED,

Harry H Hovey

Harry H. Hovey, Jr., P.E.
Director
Division of Air Resources

Figure I DECISION PROCESS


START
IS THE CHEMICAL IN TABLE I, IA, II, III, IV
NO
YES
IS THERE AN ACGIH TLV
YES
ASSUME CHEMICAL HAS MODERATE TOXICITY AAL = TLV/300
NO
REFER TO BAT FOR CHEMICAL CLASSIFICATION
IS CALCULATED AAL MET
NO
YES
1. REEVALUATE SOURCE
2. ASSISTANCE FROM BSC AND/OR BAT AVAILABLE
3. COMPLIANCE ACTION
END POINTS
IS CLASS'N HIGH, MOD., LOW
MOD or LOW TOXICITY
HIGH TOXICITY
IS IMPACT ≤ 03 µg/m³
YES
NO
ISSUE PERMIT
REFER TO BAT FOR AAL DETERMINATION
IS THERE A STATE OR FEDERAL STANDD
YES
THE STANDARD TAKES PRECEDENCE
NO
IS STANDARD MET
NO
YES
IS THERE AN AAL OR TLV
NO
YES
WHERE NO AAL EXISTS: HIGH & MOD. CHEMICAL AAL = TLV/300 LOW CHEMICAL AAL = TLV/50
IS AAL MET
YES
NO

BAT = Bureau of Air Toxics
BSC = Bureau of Source Controls

FIGURE II

CONVERSION FACTORS, et cetera

To Convert From	To	Multiply By
Pounds	Grams	453.6
Pounds	Grains	7000.
lbs/hr	μg/sec	126000.
Feet	Meters	0.3048
Feet^3	Meters^3	0.0283

$^{\circ}C = 5/9\ (^{\circ}F - 32)$

$^{\circ}K = {}^{\circ}C + 273.16$

$^{\circ}R = {}^{\circ}F + 460$

$$1\ \text{ppm} = \frac{(24.45)}{(\text{molecular weight})}\ \frac{(\text{mg})}{\text{m}^3}$$

$$1\ \text{ppb} = \frac{(24.45)}{(\text{molecular weight})}\ \frac{(\mu\text{g})}{\text{m}^3}$$

$1\ \text{pg} = 10^{-12}$ grams

$1\ \text{ng} = 10^{-9}$ grams

$1\ \mu\text{g} = 10^{-6}$ grams

$1\ \text{mg} = 10^{-3}$ grams

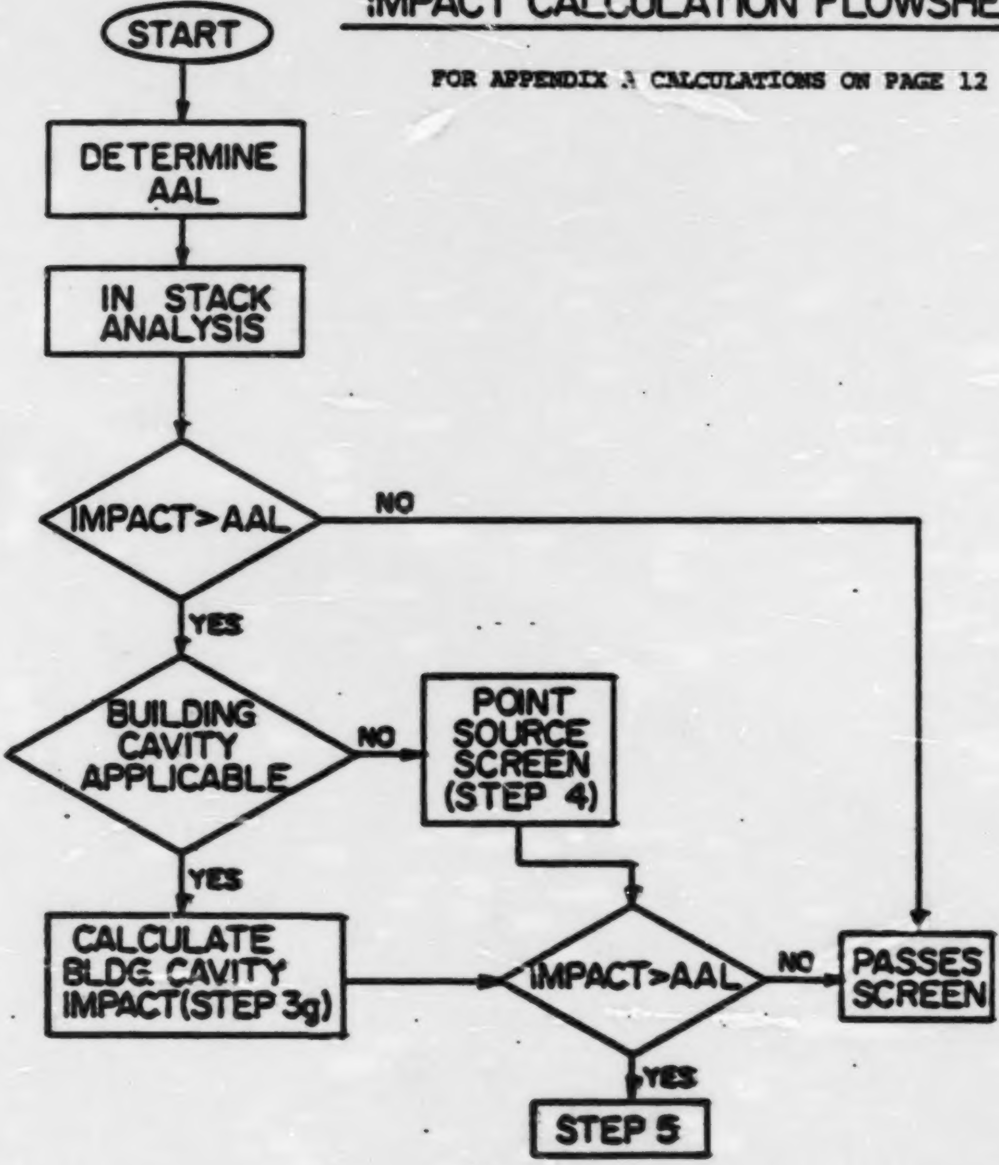
FIGURE III

GLOSSARY

Nomenclature and Variables in Appendix A: Variable	English Units	Box (English Units) Air 76-19-3	Box (English Units) ERIC
h_b = Building Height	feet	-	-
h_c = Cavity Height (of Bldg.)	feet	-	-
h_s = Stack Height	feet	Box 32	Box 42
h_e = Effective Stack Height	feet	-	-
Q = Emission Rate	lbs/hr	Box 59	Box 87
L_{max} = Maximum Horizontal Dimension	feet	-	-
F_m = Momentum Flux	ft^4/sec^2	-	--
T = Exit Temperature	°Rankine	Box 34 +460°	Box 53 +460°
V = Exit Velocity	ft/sec	Box 35	Box 43
R = Stack Outlet Diameter	inches	$\frac{(\text{Box } 33)}{24}$	$\frac{(\text{Box } 52)}{24}$
C_a = Annual Impact Concentration	$\mu g/m^3$	-	-
F = Buoyancy Flux Parameter	ft^4/sec^3	-	-
ACFM = Actual Volume Rate of Exhaust Gas	ft^3/min	Box 36	Box 48

FIGURE IV
IMPACT CALCULATION FLOWSHEET

FOR APPENDIX A CALCULATIONS ON PAGE 12


START
DETERMINE AAL
IN STACK ANALYSIS
IMPACT>AAL
NO
YES
BUILDING CAVITY APPLICABLE
NO
POINT SOURCE SCREEN (STEP 4)
YES
CALCULATE BLDG. CAVITY IMPACT(STEP 3g)
IMPACT>AAL
NO
PASSES SCREEN
YES
STEP 5

APPENDIX A

SCREENING ANALYSIS OF AMBIENT AIR QUALITY IMPACT

The stepwise procedures which follow provide a simple method of evaluating the impact of toxic contaminants on off-site receptors. The steps have been formulated to minimize the variables involved and require only information on facility emission parameters. Both point and area sources can be evaluated by the procedures.

The derivation of this method is contained in a paper entitled "Screening Procedures for Determining Ambient Impacts of Toxic Contaminants" by Leon Sedefian, Air Pollution Meteorologist IV of the DEC Bureau of Impact Assessment and Meteorology. The paper describes the assumptions and qualifications of the procedures. Section II, page 19, of this Appendix also briefly describes the assumptions and qualifications and should be reviewed prior to using the stepwise procedures.

I. STEPWISE EVALUATION OF TOXIC CONTAMINANTS

The procedures for point and area sources are described separately. The distinction of considering facility-wide emissions as point or area sources is source-receptor dependent. See subsection B (page 17), and point 8 of Section II (page 21) for general guidance on the definition of an area source. English engineering units must be consistent with the Glossary, Figure III, page 10.

A. Point Sources

1) Determine the toxicity and the corresponding AAL of the contaminant under consideration.

2) Using source parameters (i.e. volumetric flow rate and emission rate) determine the in-stack concentration. Divide the latter by 100 and compare to the AAL. If the AAL is not exceeded then no further analysis is required. If the AAL is exceeded then proceed to Step 3.

3) Cavity Impact Consideration - In some instances pollutants released from stacks and vents can be entrained into the cavity developed downwind of the building. If the cavity region extends beyond the plant property line, as defined below, the enhanced impact may be significant. The following procedures should be used to determine if cavity impacts need to be considered. If cavity impact is not significant, the Standard Point Source Impact is calculated in Step 4.

   a) Define the cavity height, h_c, as $h_c = 1.5\ h_b$, where h_b is the building height. If the release height (e.g. the physical stack height h_s) is greater than h_c no cavity impacts need be considered; skip to Step 4. If the release height is below h_c, continue with b).

   b) Define the horizontal extent of the cavity as $3h_b$. If the plant property distance exceeds $3h_b$ in all directions from the source, the cavity impacts are confined to on-site receptors. If so, proceed to Step 4. If the cavity extends beyond the plant property line proceed to c) to calculate off-site impacts.

c) Calculate the worst case annual cavity impact, C_a, from the equation:

$$C_a(\mu g/m^3) = 47420 \cdot Q/h_b^2$$

And where Q is the annual emission rate in lb/hr and h_b is in feet.

If C_a is less than the AAL, impact is not significant and no further analysis is required. If C_a exceeds the AAL, proceed to the next step which incorporates a consideration of horizontal building dimensions.

d) Determine the vertical and horizontal dimensions of the building from which emissions are released. If the building height, h_b, is less than either horizontal dimension, skip to Step 4. Otherwise define the maximum cavity length as $3L_{max}$ where L_{max} is the maximum horizontal building dimension.

If the plant property encompasses this calculated horizontal cavity dimension ($3L_{max}$) in all directions, there are no significant cavity impacts, go to Step 4. However, if the cavity region extends beyond the plant property line go to the next step.

e) Define the maximum cavity height, h_c, for the case where h_b is greater than both horizontal building dimensions as $h_c = h_b + 0.5L_{max}$ where L_{max} is defined above.

If the actual release height, h_s, (e.g. physical stack height) is greater than this cavity height, then the cavity impacts are not significant, go to Step 4. If not, continue.

f) Plume Height with Momentum Flux (This method is valid for momentum plume rise from vertically oriented emission points - No capped stacks or "goose necks")

1. Calculate Momentum Flux (F_m) from:

$$F_m = \frac{T_a}{T} \cdot V^2 \cdot R^2$$

Where: English Units

T = exit temperature = °R from Box 34+460°R
V = exit velocity = ft/sec from Box 35
R = stack outlet radius = ft, (Box 33)/24
T_a = ambient temperature = 510°R(general assumption)

2. Calculate Effective Stack Height (h_e).

$$h_e = h_s + 0.25 \cdot (F_m \cdot h_b)^{1/3}$$

If h_e is greater than h_c from Step e), the plume is assumed to escape the cavity region, proceed to Step 4. Otherwise, calculate the cavity concentrations in step g) below.

g) Calculate the worst case annual cavity concentration impact from the equation:

$$C_a(\mu g/m^3) = \frac{47420 \cdot Q}{A}$$

where:

Q = annual emission rate in lb/hr, (Box 65)

A = is the minimum vertical cross-sectional building area (ft^2) for any wind direction. i.e., $A = h_b \times L_{min}$, where L_{min} is the smaller of the horizontal building dimensions. If L_{min} exceeds $5h_b$ then set $A = 5h_b^2$ in the above equation.

h) If the cavity concentration is greater than the AAL, site specific factors such as receptor orientation must next be accounted for to confirm significance of potential impact. Consult the Impact Analysis Section at (518/457-7688) for assistance.

4) Standard Point Source Impact Calculation Methods - Two stepwise procedures are presented below to determine worst case annual concentrations from point sources. The first method uses equations and a figure for engineering parameters in English units. The second, alternate procedure is a graphical solution of the first, also using parameters in English engineering units. The latter was formulated by DEC Region 9 personnel for use with AIR-76-19-3 forms. Both procedures are simple and are presented for the choice of the user.

a) Computational Procedure - As a conservative and simple initial approximation of impact you may go directly to Step 4 below and assume that the effective stack height (h_e) is equal to the height of release (e.g. the physical stack height). If the estimated concentration exceeds the AAL then return to step 1 to account for effects of possible plume rise.

1. Determine if plume rise should be considered for a source by taking the ratio of stack height, h_s, to building height, h_b. If h_s/h_b is less than 2 set the effective stack height (h_e) equal to

h_e. Also, if the emissions are from vents or from sides of buildings, set h_e equal to the physical height of emissions. In all cases where h_e is limited to the physical height of emissions skip to Step 4, using $h_e = h_s$. Otherwise proceed to the next step.

2. Determine the buoyancy flux parameter (F) from:

$$F = 0.276 \; \frac{VR^2 \; (T-510)}{T}$$

where V, R and T are in English units as defined in Step 3f, page 12.

3. Calculate the effective stack height in feet from:

$$h_e = h_s + 7.0(F)^{3/4} \quad \text{for } F < 55$$

or

$$h_e = h_s + 12.7(F)^{3/5} \quad \text{for } F \geq 55$$

where h_s is in feet

4. Determine the annual source emission rate (Q) in lb/hr from available permit forms or stack monitored data.

5. Using the h_e value from Step 3 determine the corresponding annual concentration (C_{a1}) from Figure V, page 22. As this value is on a 1 lb/hr emission basis, multiply by Q to arrive at the annual impact for the source.

$$C_a = C_{a1} \quad Q$$

6. If C_a exceeds the AAL for the contaminant then more refined modeling should be performed as noted in Step 5 below.

b) Alternate Graphical Procedure Using Air-76-19-3 Form Data

As an alternate to method a) above, the Region 9 DEC staff has developed a graphical solution to determine standard point source impacts using data from the Process Exhaust or Ventilation System PC/CO application form (AIR 76-19-3), and two nomographs.

Nomenclature:

ACFM - (ft^3/minute) from Air 76-19-3, Box 36.

EXIT TEMP - (°F) from Air 76-19-3, Box 34

C_T - Correction for temperature from Table on Figure VI, page 23.

Q - Actual Emissions Rate (lb/hr) after air cleaning - from Air 76-19-3, Box 65.

F-line - buoyancy line on Figure VI for plume rise (P_R) determination.

P_R - plume rise in feet. Right ordinate value on Figure VI. P_R is determined by using ACFM, C_T, and F-line on Figure VI.

h_s - physical stack height above ground, in feet, from Air 76-19-3, Box 32.

h_b - height of building, in feet, from Air 76-19-3, Box 32 minus (-) Box 31.

h_e - effective stack height, in feet, where:

$h_e = h_s + P_r$; if $h_s/h_b \leq 2.0$ let $P_R = 0$

C_a - worst case annual impact at ground level in $\mu g/m^3$ for comparison to AAL.

i) Estimate the annual impact, C_a, assuming no plume rise, i.e., set $h_e = h_s$. Use Figure VII, page 24.

(a) Read h_s from box 32 of Air 76-19-3 and set h_e equal to this value.

(b) Locate this value on the left ordinate of Figure VII.

(c) Read Q (lbs/hr) from box 65 of Air 76-19-3 and locate Q on abcissa.

(d) The intersection of h_e and Q on Figure VII (interpolate) gives C_a in $\mu g/m^3$ for direct comparison to AAL. If AAL is exceeded and Step (ii) does not apply, skip to Step 5 below, if not, continue.

(ii) Estimate C_a with plume rise. Use Figures VI and VII. Use only for cases where:

$\frac{h_s}{h_b}$ >2.0, if not, go to Step 5

(a) Read EXIT TEMP (°F) from box 34 of Air 76-19-3 and locate in Table on Figure VI.

(b) Read C_T value corresponding to EXIT TEMP from this table and locate C_T on Figure 2 along top abcissa.

(c) Read ACFM from box 36 of Air 76-19-3 and locate ACFM value on Figure VI left ordinate.

(d) Locate on Figure VI the intersection of ACFM and C_T lines and go Vertically Down to F-line on graph.

(e) From F-line go horizontally to Right and read P_R in feet on the right ordinate scale.

(f) Add $P_R + h_s$ (from box 32 of Air 76-19-3) to get h_e.

(g) Locate h_e value on Figure VII ordinate.

(h) Read Q (lbs/hr) from box 65 of Air 76-19-3 and locate Q value on Figure VII abcissa.

(i) Intersection of h_e and Q above yields C_a in $\mu g/m^3$ for direct comparison with AAL.

(j) If C_a exceeds the AAL then go to Step 5.

5) Using Refined Models: Site specific modeling involves the use of an EPA recommended model such as the Climatological Dispersion Model (CDM) or the Industrial Source Complex (ISC) model (long term version). This modeling is normally requested from the source owner with the Impact Analysis Section or the Region confirming the estimates. If the results of this modeling are still unacceptable a more refined modeling should be considered which uses hourly meteorological data. The recommended model for general use is the ISC short term model unless terrain considerations are critical. The Impact Analysis Section (518/457-7688) should be consulted as to the procedures to be used in complex terrain.

6) In some instances an estimate of 15 minute (or other short term) impact may be required. To estimate short term impacts the DEC DM03 or DM04 (for building downwash effects) models should be used with the maximum expected emission rates.

B) Area Sources

The following procedures to estimate annual impacts from area sources will perform better the closer the source characteristics and assumptions approximate the conditions described below. The procedures are applicable to such sources as waste disposal sites, fugitive and primary pollutant facility-wide emissions and urban area sources. The contribution from nearby area sources can be calculated by method. Only sources located within a distance of 3S (S is the length of a side of the area source) from the source being analyzed need be considered as described in step 4 below. The method can calculate impacts at receptor distances from the source boundary to a distance of 2.5S from the area source. This range encompasses practically all cases of interest.

The procedures will perform best under the following conditions:

a) When the emissions in the area source are relatively uniformly distributed with variations not exceeding 25%.

b) When the area source is square with the emissions effectively at ground level (i.e. less than 10 feet in height).

c) When the length of a side (S) of the area source is typically 3300 feet or greater. Smaller areas can be modeled but the minimum side length should be approximately 350 feet.

d) When the emissions are continuous and not a function of meteorological conditions. (See point 9 of Section II, page 21)

The stepwise procedure is as follows:

1) Determine the area source emission rate (Q_A) in units of lb/(hr-ft^2) by dividing the total area-wide emissions rate (lb/hr) by the area (ft^2) of the source. Multiply this by 1.355 x 10^6, i.e.

$$Q_A \ \frac{\text{lb}}{\text{hr-ft}^2} = \frac{\text{(emission rate)}}{\text{(area)}}$$

2) The annual concentration within the area source is defined as:

$$C_a(\mu g/m^3) = K \cdot Q_A \cdot C_m$$

where: $K = 15$ for $330 \text{ ft} \leq S < 3300 \text{ ft}$
$K = 30$ for $S \geq 3300 \text{ ft}$
$C_m = 1.355 \times 10^6$, a conversion factor from lb/(hr-ft^2) to $\mu g/m^2$-sec).

If C_a is less than the AAL, then stop, source impact is not significant. If not, and the receptors are not within the area source, go to step 3.

3) If the receptors are located from one to 2.5 times away, divide the concentration calculated in step 2 by the following factors:

Receptor Downwind Distance	S	1.5S	2S	2.5S
Concentration Reduction Factor	7	20	25	35

4) If there are other area sources within 3S distance from the source being considered, (ideally contiguous to the source being

analyzed) then the contribution of these sources can be determined by redefining Q_A in step 1 (lb/(hr-ft^2) as:

$$Q_A = (Q_{A0} + .32Q_{A1} + .18Q_{A2} + .13Q_{A3})$$

where Q_{A0} represents the emissions from the source under consideration and Q_{A1} to Q_{A3} represent emissions from sources (if they exist) which are at upwind distances of 1S, 2S, and 3S, respectively, from the Q_{A0} source. It must be noted that the nearby sources are assumed to have about the same size as the source under consideration.

5) If the concentration is above the AAL, a site specific analysis should be performed. Consult Impact Analysis Section personnel (518/457-7688).

II. ASSUMPTIONS, QUALIFICATIONS AND FURTHER CONSIDERATIONS CONCERNING APPENDIX A

The derivation of the screening method is presented in Section III of the Sedefian paper. It should be reviewed to understand the assumptions and qualifications associated with the stepwise procedures. Some of the more commonly noted considerations are briefly discussed below:

1) Building Downwash - No Plume Rise

The assumption of $h_e = h_s$ for vents or short stack sources (Section I.4.a.1, page 14) is a rough approximation for simulating building wake effects. For the most part, it results in conservative impacts. A refined and more complex analysis would involve the use of the Industrial Source Complex model which accounts for specific source-receptor wake effects. The application of the ISC model requires the use of representative meteorological data.

2) Receptor Distance and Location

The concentrations obtained by the standard point source method (Section I.4, page 14) are valid for downwind distances greater than about 330 feet from a source and represent the maximum annual impacts at any receptor location.

3) New York County Source Impacts

For the County of New York - Manhattan, and similar urban areas - the point source procedures are not appropriate due to the constraints imposed by the possibility of large numbers of sources and receptors being located in a small geographical area. A simple method to determine the acceptability of a source's impact is to compare the emission rate of the source (in lb/hr) to Q_c where Q_c = AAL/200 and the AAL is defined in μg/m^3 for the pollutant. If the emission rate is less than Q_c then the impact of the source is acceptable as long as the size of the source is not considerably larger than the typical sources noted below. If the emission rate exceeds Q_c then appropriate DEC staff should be referred to for guidance.

The above method is derived from the analysis performed for the quantification of lead level in waste oil as discussed in the report "Determination of Acceptable Lead and Chlorine Content Limits for Waste Oil Based on Modeled Impact Results," of 12/7/82 by L. Sedefian. This analysis indicates that the NAAQS for lead of 1.5 $\mu g/m^3$ will be met by a multitude of typical sources of 1 to 10 MMBtu/hr, with average burning rate of 40 gal/hr, as long as the lead content of the waste fuel is below 25 ppm. The latter corresponds to an uncontrolled emission rate of .008 lb/hr. The above equation then simply results from the ratios of emission rates and AALs of lead or any other pollutant. It should be used for sources not larger than the typical sources just noted, which correspond to large apartment or commercial building boilers in New York County.

4) Use of Monitored Data

In situations where valid and adequate ambient monitored data are available they should be used in addition to model estimates. In most instances the monitoring information is not of sufficient duration to be representative of long term averages (it usually represents few hourly or daily averages). If this monitored data exceeds the AAL, a worst case annual impact (C_a) can be estimated from $C_a = C_{st}/10$, where C_{st} is the maximum short term concentration observed during worst case conditions of operations and meteorology. If C_a exceeds the AAL then the Impact Analysis personnel should be contacted for possible inclusion of site-specific considerations.

5) Short Term Impacts

Due to the nature of the definition of an AAL, the above screening procedures emphasize the average annual impacts and not short term effects. However, it should be noted that for the most part the procedures indirectly provide for a margin of protection against adverse short term impacts. This is based on the consideration that if annual impacts are less than 1/300 of the TLV (for high and moderate toxicity contaminants), then the short term impacts will most likely be less than the TLV. The latter conclusion is supported by comparison of refined model estimates of maximum 1 hour to annual concentrations where the ratio of 1 hour to annual impacts rarely exceeds 300.

For low toxicity contaminants it does not always follow that the short term impact will meet the TLV if the annual impact is less than 1/50 of the AAL. Thus, a model estimate might be appropriate to define worst case short term impacts. It should be noted that a review of monitoring data from various sites in the state (including isolated as well as multiple sources), indicate that even the 1/50 factor could be adequate in protecting against adverse short term impacts if the annual estimates meet the AAL.

6) Source Heights Below 33 Feet (10m)

The smallest effective stack height (h_e) for which Figure 1 was developed is 33 feet (10 meters). The graph can be extrapolated to h_e values below this, but care must be exercised in interpreting the resultant impacts. At stack heights lower that 33 feet this method will tend to overestimate impacts (dotted line), yielding very conservative results. Also, for these small h_e values the maximum impact will most likely occur within the 330 feet downwind distance noted in point (2) above which may be on plant property. In that situation, it may be prudent to assume $h_e = 33$, which yields a concentration (dashed line) which is useful in the estimation of off-site impacts.

7) Area Source Versus Multiple Point Sources

The decision between treating multiple emissions as point or area sources is dependent on specific source-receptor considerations. In general, if: (a) the emissions are from elevated sources, i.e. greater than 65 feet and/or (b) emissions are over small areas, i.e. a single building of less than 330 feet horizontal length, and (c) the receptors of interest are at a downwind distance greater than the size of the area of the emissions, then multiple point source representation is more applicable. However, in these instances the simpler area source method can still be used recognizing that the resultant impacts will be overly conservative relative to the refined multiple point source modeling.

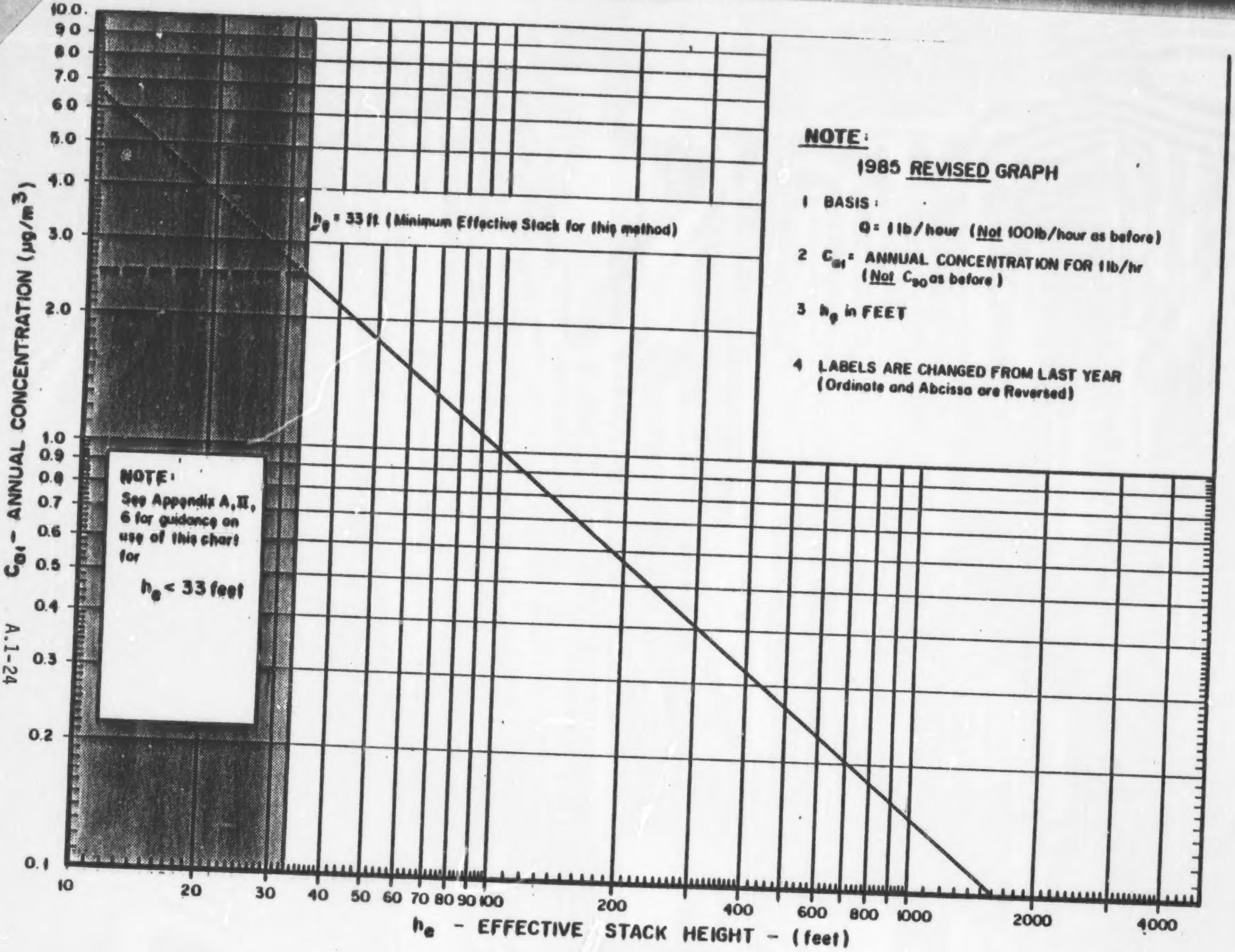
8) Multiple Point Source Impacts

A first step in the determination of multiple point source impacts is the application of the single point source screening steps to each source and the subsequent summation of all maximum impacts. For situations where the multiple sources are within the same facility and there are sources of similar emission parameters, these sources can be represented by a single point source with the combined emission rate representing Q in Section I.4)a.4, page 15. If the multiple sources represent different facilities within the same geographical area, then the maximum combined impacts should be determined for sources only within about 3 miles of the main source being analyzed.

9) A Typical Emissions and Meteorology

The annual average impacts determined by the screening method are most appropriate for continuous emissions which are not solely dependent on specific meteorological parameters, such as volatile emissions at a waste disposal site which are maximum under high ambient temperatures.

However, the screening method still will give conservative impacts under most non-standard emission conditions. In fact, for the above example the area source method will give conservative impacts since the K factor used in Section I.B.2, Page 18, would be lower for unstable atmospheric conditions which are associated with high ambient temperatures. In addition, near-field ground level source impacts are controlled by mechanical turbulence generated by the earth's surface. The area source method might not be conservative enough if emissions are controlled by stable nighttime (or other stably stratified) atmospheric conditions.



NOTE:

See Appendix A, II, 6 for guidance on use of this chart for

$h_e < 33$ feet

NOTE:

1985 REVISED GRAPH

1 BASIS:

Q = 1 lb/hour (Not 100lb/hour as before)

2 C_{a1} = ANNUAL CONCENTRATION FOR 1lb/hr (Not C_{90} as before)

3 h_e in FEET

4 LABELS ARE CHANGED FROM LAST YEAR (Ordinate and Abcissa are Reversed)

Figure V. C_a - ANNUAL CONCENTRATION (µg/m³) versus h_e - STACK HEIGHT (feet)

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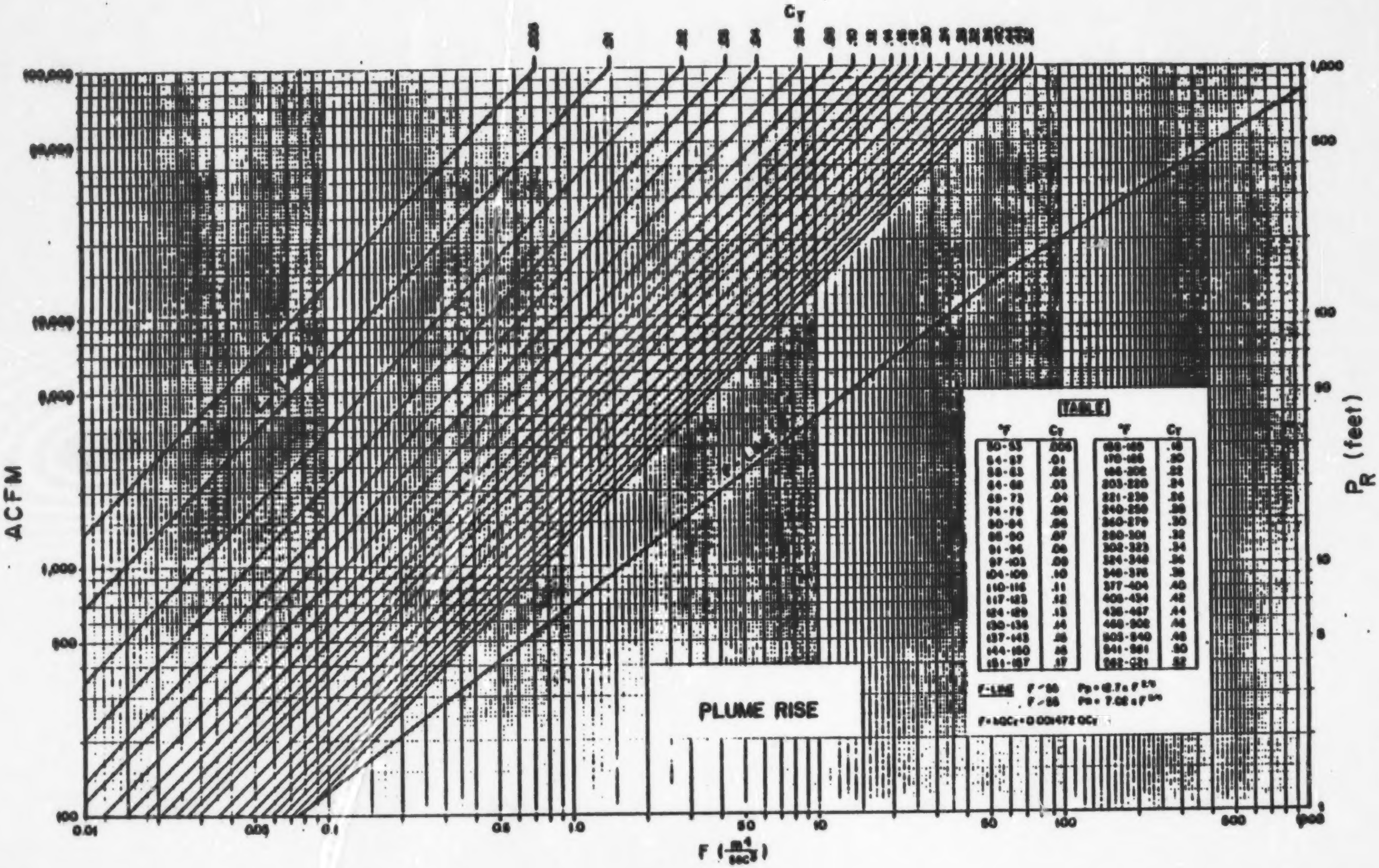

TABLE I

°F	C_T	°F	C_T
50-53	.005	158-169	.18
54-57	.01	170-185	.20
58-63	.02	186-202	.22
64-68	.03	203-220	.24
69-73	.04	221-239	.26
74-79	.05	240-259	.28
80-84	.06	260-279	.30
85-90	.07	280-301	.32
91-96	.08	302-323	.34
97-103	.09	324-346	.36
104-109	.10	348-376	.38
110-116	.11	377-404	.40
117-123	.12	405-434	.42
124-129	.13	435-467	.44
130-136	.14	468-502	.46
137-143	.15	503-540	.48
144-150	.16	541-581	.50
151-157	.17	582-621	.52

F-LINE $F < 55$ $P_R = 12.7 \times F^{0.75}$

$F > 55$ $P_R = 7.02 \times F^{0.60}$

$F = bQC_T = 0.001472\ QC_T$

Figure VI. PLUME RISE AS A FUNCTION OF STACK PARAMETERS

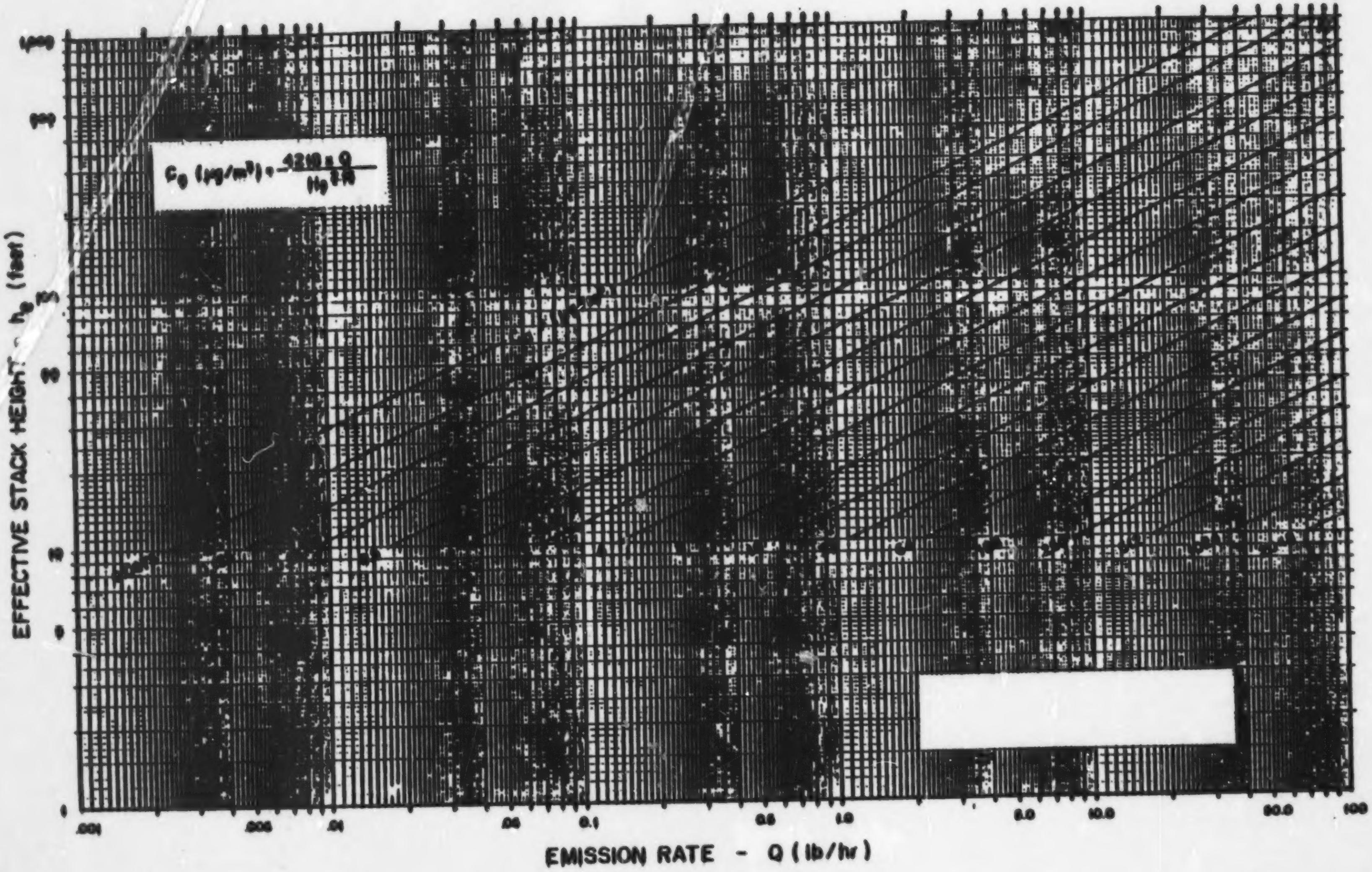

Figure VII. ANNUAL CONCENTRATION (C_a) as a function of EFFECTIVE STACK HEIGHT (h_e) and EMISSION RATE (Q)

AG-1 1/85

APPENDIX B

TOXICITY CLASSIFICATIONS

High Toxicity Air Contaminant

Definition: Human carcinogens and other substances posing a significant risk to humans.

Chemicals Assigned to High Toxicity List

1. **Human carcinogens:** Those chemicals for which the induction of cancer in humans has been demonstrated.

2. **Potential human carcinogens:** A chemical whose 1×10^{-6} lifetime risk (as calculated using GLOBAL 82)[1] corresponds to a daily dose of 0.12 µg or less. The required experimental evidence of carcinogenicity would be in: a) Two animal species; or, b) one animal species independently reproduced; or, c) one animal species supported by "short-term tests".

3. **Other substances posing a significant risk:** a) Those chemicals for which significant adverse effects have been observed in humans, particularly irreversible or progressive effects; or b) Those chemicals having an acute toxicity of:
   (a) LD_{50}(oral) is equal or less than 50 mg/kg.
   (b) LC_{50}(inhalation) is equal or less than 200 ppm.[2]
   (c) LD_{50}(dermal) is equal or less than 200 mg/kg.

Moderate Toxicity Air Contaminant

Definition: Animal carcinogens, mutagens, teratogens, and other substances posing a significant risk to humans.

Chemicals Assigned to Moderate Toxicity List

1. **Animal carcinogens:** Those chemicals for which carcinogenicity has been demonstrated in at least one species.

2. **Mutagens:** Those chemicals that induce mutagenic effects (transmissible changes) in "in-vivo" or "in-vitro" tests.

3. **Teratogens:** Those chemicals that cause non-transmissible birth defects.

---

[1] Howe, R. B. and Crump, K. S., 1982 "Global 82: A computer Program to Extrapolate Qualified Animal Toxicity Data to Low Doses", Science Research Systems, Ruston, LA.

[2] When administered by continuous inhalation exposure for ONE hour (or less if death occurs within one hour) Ref: "ANSI," American National Standards Institute, Z129.1 (1982).

4. Other substances posing a health risk to humans: a) Those chemicals that when inhaled have caused significant chronic adverse effects in test animals. In addition, they may be strong irritants to sensitive members of the population at concentrations equal to or below the TLV: or, b) Those chemicals having an acute toxicity of:
   - (a) LD_{50}(oral) is greater than 50 mg/kg but less than 500 mg/kg.
   - (b) LC_{50}(inhalation) is greater than 200 ppm but less than 2000 ppm.[2]
   - (c) LD_{50}(dermal) is greater than 200 mg/kg but less than 1000 mg/kg.

Low Toxicity Air Contaminant

Definition: Those substances whose primary concern is as an irritant. No confirmed carcinogenicity in animals.

Chemicals Assigned to Low Toxicity List:

1. No confirmed carcinogenicity: Those chemicals that have not demonstrated carcinogenicity in test animals.

2. Irritants: Those chemicals that might cause mild irritation to sensitive members of the population at concentrations below the TLV, and have no evidence of adverse effects due to chronic exposure.

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[2] By continuous inhalation exposure for one hour (or less if death occurs within one hour). Ref: See page 25.

TABLE I

SUMMARY OF FEDERAL AND STATE AMBIENT AIR STANDARDS

CONTAMINANT(1)	Averaging Period	NEW YORK STATE STANDARDS				CORRESPONDING FEDERAL STANDARDS					
						PRIMARY(5)			SECONDARY		
		Level	Conc.	Units	Statistics(2)	Conc.	Units	Stat.	Conc.	Units	Stat.
SULFUR DIOXIDE SO_2	12 Consecutive Months	ALL	0.03(3)	PPM	A.M.(Arith. Mean of 24 Hr. Avg. Conc.)	80	μg/m³	A.M.			
	24-Hr.	ALL	0.14(4)	PPM	MAX.(2)	365	μg/m³	MAX.(2)			
	3-Hr.	ALL	0.50	PPM	MAX.				1300	μg/m³	MAX.
CARBON MONOXIDE (CO)	8-Hr.	ALL	9	PPM	MAX.	10	mg/m³	MAX.	10	mg/m³	MAX.
	1-Hr.	ALL	35	PPM	MAX.	40	mg/m³	MAX.	40	mg/m³	MAX.
OZONE (PHOTOCHEMICAL OXIDANTS)	1-Hr.	All(6)	0.12	PPM	MAX.	235	μg/m³	MAX.	235	μg/m³	MAX.
BERYLLIUM	1-Month	ALL	0.01	μg/m³	A.M.	0.01	μg/m³(8)	A.M.			
NITROGEN DIOXIDE	12 Consecutive Months	ALL	0.05	PPM	A.M.	100	μg/m³	A.M.	100	μg/m³	A.M.
LEAD	3 Consecutive Mos.	(7)				1.5	μg/m³	MAX.			
FLUORIDES	24-Hr.	ALL	2.85	μg/m³	A.M.						
HYDROGEN SULFIDE	1- Hr.	ALL	0.01	PPM	A.M.						

(1) N.Y.S. also has standards for hydrocarbons, suspended and settleable particulates. Do not use Appendix A methods for determining compliance with TSP standards.

(2) All maximum values are not to be exceeded more than once a year (Ozone standard not be exceeded during more than one day per year).

(3) Also during any 12 consecutive months, 99% of the values shall not exceed 0.10 PPM (not necessary to address this standard when predicting future concentrations).

(4) Also during any 12 consecutive months, 99% of the values shall not exceed 0.25 PPM (see above).

(5) Gaseous concentrations are corrected to a reference temperature of 25°C and to a reference pressure of 760 mmHg.

(6) Existing N.Y.S. standard for Photochemical Oxidants (Ozone) of 0.08 PPM not yet officially revised via regulatory process to coincide with new Federal standard of 0.12 PPM which is currently being applied to determine compliance status.

(7) New Federal standard for lead not yet officially adopted by N.Y.S., but is currently being applied to determine compliance status.

(8) 30-day average Federal NESHAP (National Emission Standard for Hazardous Air Pollutants) Standard value listed.

TABLE IA

NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS (NESHAPS)

ARSENIC

ASBESTOS[1]

BENZENE (Fugitive Emission Sources)

BERYLLIUM

MERCURY

RADIONUCLIDES

VINYL CHLORIDE

Appropriate standards for each of the above are found in 40 CFR 61.

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[1] See Asbestos listing Table II, page 29.

TABLE II

High Toxicity Air Contaminants

Compound Chemical Name	CAS Registry Number	Threshold Limit Value(1) (TLV's) PPM	mg/m^3	AAL(2) Recommended µg/m^3
Acrolein	107-02-8	0.1	0.25	0.83(T)
Acrylonitrile	107-13-1	2.0	4.5	15.0(T)
Aldicarb	116-06-3	-	-	2.0(DOH/R)
p-Aminodiphenyl	92-67-1	-	-	(HAZ)(3)
Arsenic	7440-38-2	-	0.2	0.67(T)
Arsenic pentoxide	1303-28-2	-	-	see (4)
Arsenic trioxide	1327-53-3	-	-	see (4)
Asbestos(5)	1332-21-4	2 Fibers > 5 µm/cc		
Auramine	2465-27-2	-	-	see (4)
Benzene	71-43-2	10	30	100.(T)
Benzidine	92-87-5	-	-	(HAZ)
Beryllium oxide (As Beryllium, See Tables I & IA)	1304-56-9	-	.002	.007(T)
Beryllium sulfate	13510-49-1	-	.002	.007(T)
Cadmium (dust and salts) as Cd	7440-43-9	-	0.05	2.0(DOH/R)
Cadmium oxide	1306-19-0	-	0.05	0.167(T)
Cadmium sulfate	10124-36-4	-	0.005	0.167(T)
Carbon tetrachloride	56-23-5	5	30	100(T).
bis-Chloromethyl ether	542-88-1	0.001	0.005	0.017(T)(HAZ)
Chromium VI Compounds (note: CAS listed assigned to metallic chromium)	7440-47-3	-	0.05	0.167(T)
Dibromoethane (Ethylene dibromide)	106-93-4	-	-	see (4)
3,3'-Dichlorobenzidine	91-94-1	-	-	0.1(DOH/R)

TABLE II

High Toxicity Air Contaminants (cont.)

Compound Chemical Name	CAS Registry Number	Threshold Limit Value[1] (TLV's)		AAL[2] Recommended µg/m³
		PPM	mg/m³	
Dimethyl sulfate	77-78-1	0.1	0.5	1.67(T)
Ethyleneimine	151-56-4	0.5	1.0	3.3(T)
Ethylene oxide	75-21-8	1.0	2.0	6.67(T)
Formaldehyde	50-00-0	1	1.5	5(T)[6]
Hydrazine and its acid salts	302-01-2	0.1	0.1	0.33(T)
Lead arsenate	7784-40-9	-	0.15	0.5(T)
Methylene bisphenyl isocyanate, (Diphenylmethane-4, 4-diisocyanate) (DMI)	101-68-8	C0.02	C0.2[7]	0.67(T)
Methyl isocyanate (MIC)	624-83-9	0.02	0.05	0.17(T)
β-Naphthylamine	91-59-8	-	-	(HAZ)
Nickel (metal and insoluble compounds)	7440-02-2	-	1.0	3.3(T)
Nickel carbonyl	13463-39-3	0.05	0.35	1.17(T)
Nickel oxide	1313-99-1	-	1.0	3.37(T)
Nickel sulfide, as Ni	12035-72-2	-	1.0	0.1(DOH/R)(HAZ)
4-Nitrodiphenyl	92-93-3	-	-	(HAZ)
Nitrogen mustard	51-75-2	-	-	see (4)
Nitrosodimethylamine (dimethylnitrosoamine)	62-75-9	-	-	see (4)
Parathion	56-38-2	-	0.1	0.33(T)
Polychlorinated biphenyls (PCBs) (TLV assigned to Aroclor 1254)	1336-36-3	-	0.5	1.67(T)
Polycyclic Organic Matter[8] (includes Benzo(α)Pyrene)	50-32-8	-	-	see (4)

TABLE II

High Toxicity Air Contaminants (cont.)

Compound Chemical Name	CAS Registry Number	Threshold Limit Value(1) (TLV's) PPM	Threshold Limit Value(1) (TLV's) mg/m^3	AAL(2) Recommended µg/m^3
2,3,7,8-Tetrachloro-dibenzofuran	51207-31-~~0~~9	-	-	see (9)
Total Tetrachlorinated dibenzo-p-dioxins (includes 2,3,7,8TCDD)	174~~0~~6-01-~~7~~6	-	-	see (9)
Toluene-(2,4)-diisocyanate (TDI)	584-84-0	0.005	0.04	0.13(T)
Vinyl chloride (Chloroethylene)	75-01-4	-	-	0.4(DOH/R)(HAZ)
Vinylidene chloride (1,1-Dichloroethylene)	75-35-4	5	20	66.7(T)

NOTE: Radioactive materials are not included in this table as they are regulated by Part 380 of DEC's Rules and Regulations.

Table II Footnotes:

1 1984-85 ACGIH values.

2 AAL, "Acceptable Ambient Level", source:
(T) - Interim AAL derived from ACGIH TWA-TLV
(DOH) - Contaminant specific AAL determined by NYS DOH Bureau of Toxic Substance Assessment;
(DOH/R) - Contaminant specific AAL currently under review by DOH.
(DEC) - Contaminant specific AAL determined by NYS DEC, Division of Air Resources, Bureau of Air Toxics, Toxics Assessment Section.

3 (HAZ) - "Human Carcinogens. Substances, or substances associated with industrial processesses recognized to have carcinogenic potential without an assigned TLV... for [these noted] substances,... no exposure or contact by any route - respiratory, skin or oral, as detected by the most sensitive methods - shall be permitted." From: "TLV's, Threshold Limit Values for Chemical Substances...ACGIH for 1984-85", Appendix A - Carcinogens, Table A1b., page 41.

4 No chemical specific TLV or AAL available at this time, see "High Toxicity Air Contaminants," pages 2 and 3, for guidance.

5 OSHA Temporary Standard: 0.5 fibers per c.c. (see Fed. Reg., 48, No. 215, page 51086, 1983). Not applicable to sources subject to NESHAPS.

6 Interim formaldehyde AAL of 5 µg/m^3 calculated from AG-1 guidance for High Toxicity Air Contaminants, section I, paragraph B, page 3. This interim value replaces previously listed AAL of 2.0 µg/m^3. NYSDOH to provide a chemical specific formaldehyde AAL by 4/1/86.

7 "C" denotes ACGIH TLV-C,"ceiling limit". "The concentration that should not be exceeded even instantaneously".

8 Containing large amounts of naphthalene, fluorene, anthracene, and acridine.

9 **NOTE:** NYSDOH has determined that for "AAL's for dioxins... Basing an acceptable ambient level on only total TCDD's as is now done in 'Air Guide-1' (1984 and earlier editions) does not adequately represent public health risks for the dioxin compounds... Health risks posed by emissions of chlorinated dioxins and the closely related chlorinated furans should be evaluated on a case by case basis taking into consideration specific isomers of each family of compounds."

Based on the above statement by NYSDOH; noting the legislative mandate for DOH to develop resource recovery related standards (including TCDD & TCDF); and DOH's April 1, 1986 deadline for such standards, DEC is withdrawing the 9.2×10^{-8} μg/m^3, "Hernandez," TCDD interim AAL* at this time.

Emission sources of chlorinated dibenzofurans and dibenzodioxins will be reviewed on a case by case basis by DOH until the standards are promulgated. Direct all inquiries on this matter to the Toxics Management Section of DEC.

* EPA's Interim Evaluation of Health Risks Associated with Emissions of Tetrachlorinated Dioxins from Municipal Waste Recovery Facilities, November 1981.

TABLE III

Moderate Toxicity Organic Air Contaminants

Compound-(ORGANICS) Chemical Name	CAS Registry Number	Threshold Limit Values(1) (TLV's) PPM	mg/m^3	AAL(2) Recommended µg/m^3
Acetaldehyde	75-07-0	100	180	600(T)
Acetamide	60-35-5	-	-	(DM)(3)
Acetic anhydride	108-24-7	C5(4)	C20	66.7(T)
2-Acetylaminofluorene	53-96-3	-	-	(DM)
Acrylamide	79-06-1	-	0.3	1.0(T)
Acrylic acid	79-10-3	10	30	100(T)
Allyl chloride (3-Chloro-1-propene)	107-05-1	1	3	10(T)
Aniline	62-53-3	2	10	0.4(DOH)
p-Anisidine	104-94-9	0.1	0.5	1.7(T)
Arsine	7784-42-1	0.05	0.2	0.67(T)
Benzyl chloride	100-44-7	1	5	16.7(T)
Biphenyl	92-52-4	0.2	1.5	5(T)
Butanethiol (Butyl Mercaptan)	109-79-5	0.5	1.5	5(T)
n-Butylamine	109-73-9	C5	C15	50(T)
Carbon black	1333-86-4	-	3.5	11.7(T)
Carbon disulfide	75-15-0	10	30	100(T)
Chlordane	57-74-9	-	0.5	1.7(T)
Chlordecone (Kepone)	143-50-0	-	-	(DM)
α-Chloroacetophenone (Phenacyl chloride)	532-27-4	0.05	0.3	1(T)
p-Chloroaniline	106-47-8	-	-	6.0(DOH/R)
Chlorobenzene (monochlorobenzene)	108-90-7	75	350	1167(T)
Chloroform	67-66-3	10	50	167(T)

TABLE III

Moderate Toxicity Organic Air Contaminants (cont.)

Compound-(ORGANICS) Chemical Name	CAS Registry Number	Threshold Limit Values$^{(1)}$ (TLV's) PPM	mg/m^3	AAL$^{(2)}$ Recommended μg/m^3
p-Chloronitrobenzene	100-00-5	(see p-Nitrochlorobenzene below)		
o-Cresol	95-48-7	5.0	22	73(T)
m-Cresol	108-39-4	5.0	22	73(T)
p-Cresol	106-44-5	5.0	22	73(T)
Cyanamide	420-04-2	-	2	6.7(T)
Cyanides (As CN)	57-12-5	-	5	16.7(T)
Cyanic acid (Sodium Salt)	917-61-3	see Cyanogen below		
Cyanic acid (Potassium Salt)	590-28-3	see Cyanogen below		
Cyanoacetamide	107-91-5	see Cyanides above		
Cyanogen (Oxalonitrile)	460-19-5	10	20	66.7(T)
Diallylamaleate	999-21-3	-	-	6(DEC)
2,5-Diamino toluene	95-70-5	-	-	(DM)
Diazomethane	334-88-3	0.2	0.4	1.3(T)
o-Dichlorobenzene	95-50-1	C50	C300	1,000(T)
1,2-Dichloroethane (Ethylene Dichloride)	107-06-2	10	40	0.2(DOH/R)
Dichloromethane (Methylene Chloride)	75-09-2	100	350	1167.(T)
Diethyl phthalate	84-66-2	-	5	16.7(T)
Diisodecyl phthalate	26761-40-0	see Diethyl phthalate above		
3,3'-Dimethoxybenzidine (o-Dianisidine)	119-90-4	-	-	0.2(DOH/R)
4-Dimethylaminoazobenzene	60-11-7	-	-	(DM)

TABLE III

Moderate Toxicity Organic Air Contaminants (cont.)

Compound-(ORGANICS) Chemical Name	CAS Registry Number	Threshold Limit Values(1) PPM	(TLV's) mg/m^3	AAL(2) Recommended µg/m^3
Dimethyl carbamoyl chloride	79-44-7	-	-	(DM)
1,1-Dimethyl hydrazine	57-14-7	0.5	1	3.3(T)
m-Dinitrobenzene	99-65-0	0.15	1	3.3(T)
Dioctyl phthalate (DOP)	117-81-7	see Diethylphthalate above		
p-Dioxane	123-91-1	25	90	300(T)
Diphenyl hydrazine	122-66-7	see Dimethyl hydrazine above		
Epichlorohydrin (1-Chloro-2,3-epoxy propane)	106-89-8	2	10	33.3(T)
Epoxypropane (Propylene oxide)	75-56-9	20	50	167(T)
Ethanethiol (Ethyl mercaptan)	75-08-1	0.5	1	3.3(T)
Ethanolamine	141-43-5	3	8	26.7(T)
Ethyl benzene	100-41-4	100	435	1450(T)
Ethyleneglycol Monopropyl ether	2807-30-9	-	-	70(DEC)
Formamide	75-12-7	20	30	100(T)
Formic acid	64-18-6	5	9	30(T)
Furfural	98-01-1	2	8	26.7(T)
Furfuryl alcohol	98-00-0	10	40	133(T)
Glycidaldehyde	765-34-4	-	-	(DM)
Heptachlor	76-44-8	-	0.5	1.7(T)
Hexachlorobenzene	118-74-1	-	-	(DM)
Hexachlorobutadiene	87-68-3	0.02	0.24	0.8(T)
Hexachlorocyclohexane (1,2,3,4,5,6, Hexachlorocyclohexane)	319-84-6	See α Lindane, page 36		

TABLE III

Moderate Toxicity Organic Air Contaminants (cont.)

Compound-(ORGANICS) Chemical Name	CAS Registry Number	Threshold Limit Values(1) (TLV's) PPM	Threshold Limit Values(1) (TLV's) mg/m^3	AAL(2) Recommended µg/m^3
Hexachlorocyclopentadiene	77-47-4	0.01	0.1	0.33(T)
Hexachloronapthalene	1335-87-1	-	0.2	0.67(T)
Hexamethyl phosphoramide	680-31-9	-	-	(DM)
Hydrogen cyanide (Hydrocyanic acid)	74-90-8	C10	C10	33(T)
Hydrogen Fluoride	7664-39-3	C3	C2.5	8.3(DEC)
Hydroquinone	123-31-9	-	2	6.67(T)
Isophorone	78-59-1	C5	C25	83.3(T)
Isopropyl Alcohol(5)	67-63-0	400	980	3267(T)
Isopropylamine	75-31-0	5	12	40(T)
Ketene	463-51-4	0.5	0.9	3.33(T)
α-Lindane	319-84-6	-	0.5	1.67(T)
γ-Lindane	58-89-9	-	0.5	1.67(T)
Malathion	121-75-5	-	10	33.3(T)
Maleic anhydride	108-31-6	0.25	1	3.3(T)
Mercury (organic) (non-NESHAPS sources)	7439-97-6	-	0.05	0.167(T)
2-Methoxyethanol (Methyl cellosolve)	109-86-4	5	16	53.3(T)
Methylamine	74-89-5	10	12	40.(T)
Methyl chloromethylether	107-30-2	-	-	(DM)
4,4'-Methylene dianiline	101-77-9	0.1	0.8	2.67(T)
Methylethyl ketone (MEK)	78-93-3	200	590	1967(T)

TABLE III

Moderate Toxicity Organic Air Contaminants (cont.)

Compound-(ORGANICS) Chemical Name	CAS Registry Number	Threshold Limit Values(1) (TLV's)		AAL(2) Recommended µg/m³
		PPM	mg/m³	
Methyl hydrazine (monomethyl hydrazine)	60-34-4	C0.2	C0.35	1.17(T)
Methyl isobutyl ketone	108-10-1	50	205	683(T)
Methyl mercaptan	74-93-1	0.5	1.0	3.3(T)
Methyl methacrylate	80-62-6	100	410	1367(T)
Mirex	2385-85-5	-	-	(DM)
Monochlorobenzene	108-90-7	See chlorobenzene above		
Monomethyl hydrazine	60-34-4	See methyl hydrazine above		
Naphthalene	91-20-3	10	50	166.7(T)
α-Naphthylamine	134-32-7	-	-	(DM)
Nitrilotriacetic acid	139-13-9	-	-	(DM)
p-Nitroaniline	100-01-6	-	3	6.0(DOH/R)
Nitrobenzene	98-95-3	1	5	16.7(T)
Nitroglycerine	55-63-0	0.05	0.5	1.67 ~~16.7~~(T)
p-Nitrochlorobenzene	100-00-5	-	1	3.3(T)
p-Nitrophenol	100-02-7	-	-	(DM)
1-Nitropropane	108-03-2	25	90	300(T)
Nitroso-n-methylurea	684-93-5	-	-	(DM)
p-Nitrosophenol	104-91-6	-	-	(DM)
p-Nitrotoluene	99-99-0	2	11	36.7(T)
Octachloronaphthalene	2234-13-1	-	0.1	0.33(T)
Oil Mist (Mineral)	8012-95-1	-	5(6)	16.7(T)
Oxalic acid	144-62-7	-	1	3.3(T)

TABLE III

Moderate Toxicity Organic Air Contaminants (cont.)

Compound-(ORGANICS) Chemical Name	CAS Registry Number	Threshold Limit Values(1) (TLV's) PPM	mg/m^3	AAL(2) Recommended μg/m^3
Paraquat	1910-42-5	-	0.1	0.33(T)
Pentachlorophenol	87-86-5	-	0.5	1.67(T)
Perchloroethylene	127-18-4	See tetrachloroethylene below		
Petroleum distillates	8002-05-9	-	-	(DM)
Phenol	108-95-2	5	19	10.0(DOH)
p-Phenylene diamine	106-50-3	-	0.1	0.33(T)
Phenylhydrazine	100-63-0	5	20	66.7(T)
Phosgene	75-44-5	0.1	0.4	1.33(T)
Phosphine	7803-51-2	0.3	0.4	1.33(T)
Picric acid	88-89-1	-	0.1	0.33(T)
Propane sultone	1120-71-4	-	-	(DM)
β-Propiolactone	57-57-8	0.5	1.5	5.0(T)
Pyrethrin	121-29-9	See Pyrethrum		
Pyrethrum	8003-34-7	-	5.	16.7(T)
Quinoline	91-22-5	-	-	(DM)
Quinone	106-51-4	0.1	0.4	1.33(T)
Rotenone (commercial)	83-79-4	-	5	1.67(T)
Styrene, monomer	100-42-5	50	215	716(T)
1,1,2,2-Tetrachloroethane	79-34-5	1	7	23.3(T)
Tetrachloroethylene (Perchloroethylene)	127-18-4	50	335	1116(T)
Thiourea	62-56-6	-	-	(DM)
Toluene-(2,4)-diamine	95-80-7	-	-	(DM)

TABLE III

Moderate Toxicity Organic Air Contaminants (cont.)

Compound-(ORGANICS) Chemical Name	CAS Registry Number	Threshold Limit Values[1] (TLV's)		AAL[2] Recommended µg/m³
		PPM	mg/m³	
o-Toluidine	95-53-4	2	9	30(T)
Toxaphene (chlorinated camphene)	8001-35-2	-	0.5	1.67(T)
1,2,4-Trichlorobenzene	120-82-1	C5	C40	133(T)
1,1,2-Trichloroethane	79-00-5	10	45	150(T)
Trichloroethylene	79-01-6	50	270	900(T)
Urethane (Carbamic acid)	51-79-6	-	-	(DM)
Vinyl bromide	593-60-2	5	20	66.7(T)
Vinyl fluoride	75-02-2	See Vinyl bromide		
o-Xylene (note: CAS 1300-20-7 assigned to mixed isomer xylenes)	95-47-6	100	435	1450(T)
m-Xylene	108-38-3	100	435	1450(T)
p-Xylene	106-42-3	100	435	1450(T)
Xylidine	1300-73-8	2.0	10	33.3 (T)

TABLE III

Moderate Toxicity Inorganic Air Contaminants

Compound-(INORGANICS) Chemical Name	CAS Registry Number	Threshold Limit Values(1) (TLV's) PPM	mg/m³	AAL(2) Recommended µg/m³
Ammonium bromide	12124-97-9	-	-	30.0(DEC)
Antimony	7440-36-0	-	0.5	0.67(T)
Antimony trioxide	1309-64-4	-	0.5	0.67(T)
Barium	7440-39-3	-	0.5	0.67(T)
Barium sulfate	7727-43-7	-	-	(DM)
Bromine	7726-95-6	0.1	0.7	2.33(T)
Cadmium chloride (as Cd salt)	10108-64-2	-	0.05	1.67(T)
Chlorine	7782-50-5	1	3	10(T)
Chlorine dioxide	10049-04-4	0.1	0.3	1(T)
Cobalt	7440-48-4	-	0.1	0.33(T)
Cobalt oxide	1307-96-6	-	-	(DM)
Cobalt sulfide	1317-42-6	-	-	(DM)
Fluorine	7782-41-4	1	2	6.7(T)
Lead acetate	1335-32-6	-	-	(DM)
Mercury (inorganic) (non-NESHAPS sources)	7439-97-6	-	0.1	0.33(T)
Phosphorous (yellow)	7723-14-0	-	0.1	0.33(T)
Selenium	7782-49-2	-	0.2	0.66(T)
Selenium sulfide	7488-56-4	-	0.2	0.66(T)
Thallium(7)	7440-28-0	-	0.1	0.33(T)
Thallium oxide	1314-32-5	-	0.1	0.33(T)

TABLE III

Moderate Toxicity Inorganic Air Contaminants (cont.)

Compound-(INORGANICS) Chemical Name	CAS Registry Number	Threshold Limit Values[1] (TLV's) PPM	Threshold Limit Values[1] (TLV's) mg/m³	AAL[2] Recommended µg/m³
Thallium (I) selenite	12039-52-0	-	0.1	0.33(T)
Thallium sulfate	7446-18-6	-	0.1	0.33(T)
Zinc bromide	7699-45-8	-	-	3.0(DEC)
Zinc chloride (fume)	7646-85-7	-	1	3.3(T)
Zinc oxide (fume)	1314-13-2	-	5	16.7(T)

(1) 1984-85 ACGIH values.

(2) AAL, "Acceptable Ambient Level," source:
(T) - Interim AAL derived from ACGIH TWA-TLV, see text, page 4.
(DOH) - Contaminant specific AAL determined by NYS DOH, Bureau of Toxic Substance Assessment;
(DOH/R) - Contaminant specific AAL currently under review by DOH.
(DEC) Contaminant specific AAL determined by NYS DEC, Division of Air Resources, Bureau of Air Toxics, Toxics Assessment Section.

(3) (DM) denotes "de minimus" Interim AAL of 0.03 µg/m³ is recommended for use with Appendix A screening methodology. No chemical specific TLV or AAL is available at this time.

(4) "C" denotes ACGIH TLV-C, "ceiling limit". "The concentration that should not be exceeded even instantaneously."

(5) The higher degree of toxicity is due to isopropyl oil, a common manufacturing by-product.

(6) Oil Mist (mineral) as sampled by a method which does not collect vapor.

(7) The TLV of 0.1 mg/m³ is for soluble thallium compounds, as Tl. Thallium readily oxidizes in air at room temperature.

TABLE IV

Low Toxicity Organic Air Contaminants

Compound-(ORGANICS) Chemical Name	CAS Registry Number	Threshold Limit Values(1) (TLV's) PPM	mg/m³	AAL(2) Recommended µg/m³
Acetone	67-64-1	750	1780	35600(T)*
Acetonitrile	75-05-8	40	70	1400(T)
n-Butyl acetate	123-86-4	150	710	14200(T)
n-Butyl alcohol	71-36-3	C50(3)	C150	3000(T)
Butyl benzyl phthalate	85-68-7	-	5(4)	100(T)
Chloromethane (Methyl chloride)	74-87-3	50	105	2100(T)
Cyclohexane	110-82-7	300	1050	21000(T)
Diethyl ether (1,1'-Oxybis-ethane)	60-29-7	(See Ethyl ether, below)		
Dioctyl sebacate	122-62-3	-	-	80.0(DEC)
Ethyl acetate	141-78-6	400	1400	28000(T)
Ethyl chloride	75-00-3	1000	2600	52000(T)
Ethyl ether (Diethyl ether, ethers)	60-29-7	400	1200	24000(T)
Glycerin Mist(5)	56-81-5	-	10	200(T)
Glycol monoethylether (2-Ethoxyethanol)	110-80-5	5	9	180(T)
n-Heptane	142-82-5	400	1600	32000(T)
Isoamyl acetate	123-92-2	100	525	10500(T)
Isoamyl alcohol	123-51-3	100	360	7200(T)
Isobutyl acetate	110-19-0	150	700	14000(T)
Pyridine	110-86-1	5	15	2.0(DOH/R)
Resorcinol	108-46-3	10	45	900(T)

TABLE IV

Low Toxicity Organic Air Contaminants (cont.)

Compound-(ORGANICS) Chemical Name	CAS Registry Number	Threshold Limit Values (TLV's)(1) PPM	Threshold Limit Values (TLV's)(1) mg/m³	AAL(2) Recommended µg/m³
Tetrahydrofuran	109-99-9	200	590	11800(T)
Toluene (Toluol)	108-88-3	100	375	7500(T)
1,1,1-Trichloroethane (Methyl chloroform)	71-55-6	350	1900	38000(T)
Turpentine	8006-64-2	100	560	11200(T)
Urea	57-13-6	-	-	(DM)

* **NOTE:** 1000 $\mu g/m^3$ = 1 mg/m^3

TABLE IV

Low Toxicity Inorganic Air Contaminants

Compound-(INORGANICS) Chemical Name	CAS Registry Number	Threshold Limit Values (1) (TLV's) PPM	mg/m³	AAL (2) Recommended µg/m³
Ammonia	7664-41-7	25	18	360(T)
Copper, (fume)	7440-50-8	-	0.2	4(T)
Copper, (dusts and mists, as Cu)	7440-50-8	-	1	20(T)
Hydrogen bromide	10035-10-6	C3	C10	200(T)
Hydrogen chloride	7647-01-0	C5	C7	140(T)
Iodine	7553-56-2	C0.1	C1	20(T)
Nitric acid	7697-37-2	2	5	100(T)
Zinc	7440-66-6	-	-	(DM) (6)

(1) 1984-85 ACGIH values.

(2) AAL, "Acceptable Ambient Level," source:
(T) - Interim AAL derived from ACGIH TWA-TLV.
(DOH) - Contaminant specific AAL determined by NYS DOH, Bureau of Toxic Substance Assessment;
(DOH/R) - Contaminant specific AAL currently under review by DOH.
(DEC) - Contaminant specific AAL determined by NYS DEC, Division of Air Resources, Bureau of Air Toxics, Toxics Assessment Section.

(3) "C" denotes ACGIH TLV-C, "ceiling limit". "The concentration that should not be exceeded even instantaneously." - 1984-85 ACGIH TLV booklet.

(4) TLV assigned to Diethyl phthalate.

(5) See "Appendix D - Some Nuisance Particulates," page 50; and "Notice of Intended Changes (for 1984-85)", page 36 and especially page 40 ("Generic Listing"), of the 1984-85 ACGIH TLV booklet.

(6) (DM) denotes "de minimus" Interim AAL of 0.03 µg/m³ is recommended for use with Appendix A screening methodology. No chemical specific TLV or AAL is available at this time.

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Updated: 2/7/85

Appendix A.2

CHEMICAL HAZARD
INFORMATION PROFILES
THROUGH SEPTEMBER 28, 1984
(CHIPs AVAILABLE FROM TAO)

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
ACETALDEHYDE	
75-07-0	ACETALDEHYDE
ACETALDEHYDE-2	
75-07-0	ACETALDEHYDE
ACETONITRILE	
75-05-8	ACETONITRILE
ACROLEIN	
107-02-8	2-PROPENAL
107-02-8	ACROLEIN
ACRYLIC ACID	
79-10-7	2-PROPENOIC ACID
79-10-7	ACRYLIC ACID
ADIPATE ESTER PLASTICIZERS	
NONE	ADIPATE ESTER PLASTICIZERS
103-23-1	HEXANEDIOIC ACID, BIS(2-ETHYLHEXYL) ESTER
105-97-5	HEXANEDIOIC ACID, DIDECYL ESTER
105-99-7	HEXANEDIOIC ACID, DIBUTYL ESTER
105-99-7	HEXANEDIOIC ACID, DIBUTYL ESTER
106-19-4	HEXANEDIOIC ACID, DIPROPYL ESTER
110-29-2	HEXANEDIOIC ACID, DECYL OCTYL ESTER
110-32-7	DI(2-HEXYLOXYETHYL)ADIPATE
123-79-5	HEXANEDIOIC ACID, DIOCTYL ESTER
141-04-8	HEXANEDIOIC ACID, BIS(2-METHYLPROPYL) ESTER
141-17-3	HEXANEDIOIC ACID, BIS(2-(2-BUTOXYETHOXY)ETHYL)ESTER
141-28-6	HEXANEDIOIC ACID, DIETHYL ESTER
151-32-6	HEXANEDIOIC ACID, DINONYL ESTER
627-93-0	HEXANEDIOIC ACID, DIMETHYL ESTER
849-99-0	HEXANEDIOIC ACID, DICYCLOHEXYL ESTER
1330-86-5	HEXANEDIOIC ACID, DIISOOCTYL ESTER
7790-07-0	DI(2-(2-ETHYLBUTOXY))ETHYL ADIPATE
10022-60-3	DI(2-ETHYLBUTYL)ADIPATE
22707-35-3	N-HEXYL N-DECYL ADIPATE
25101-03-5	HEXANEDIOIC ACID, POLYMER WITH 1,2-PROPANEDIOL
27178-16-1	HEXANEDIOIC ACID, DIISODECYL ESTER
ALKYL PHTHALATES	
NONE	ALKYL PHTHALATES
UNKNOWN	BUTYL ISODECYL PHTHALATE
UNKNOWN	HEXYL ISOOCTYL PHTHALATE
UNKNOWN	ISOOCTYL ISODECYL PHTHALATE
84-61-7	1,2-BENZENEDICARBOXYLIC ACID, DICYCLOHEXYL ESTER
84-64-0	1,2-BENZENEDICARBOXYLIC ACID, BUTYL CYCLOHEXYL ESTER
84-66-2	1,2-BENZENEDICARBOXYLIC ACID, DIETHYL ESTER

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
84-69-5	1,2-BENZENEDICARBOXYLIC ACID, BIS(2-METHYLPROPYL) ESTER
84-72-0	ETHYL PHTHALYL ETHYL GLYCOLATE
84-74-2	1,2-BENZENEDICARBOXYLIC ACID, DIBUTYL ESTER
84-75-3	1,2-BENZENEDICARBOXYLIC ACID, DIHEXYL ESTER
84-76-4	1,2-BENZENEDICARBOXYLIC ACID, DINONYL ESTER
84-78-6	1,2-BENZENEDICARBOXYLIC ACID, BUTYL OCTYL ESTER
85-68-7	1,2-BENZENEDICARBOXYLIC ACID, BUTYL PHENYLMETHYL ESTER
85-69-8	1,2-BENZENEDICARBOXYLIC ACID, BUTYL 2-ETHYLHEXYL ESTER
85-70-1	1,2-BENZENEDICARBOXYLIC ACID, 2-BUTOXY-2-OXOETHYL BUTYL ESTER
85-71-2	METHYL PHTHALYL ETHYL GLYCOLATE
89-13-4	1,2-BENZENEDICARBOXYLIC ACID, 2-ETHYLHEXYL 8-METHYLNONYL ESTER
89-19-0	N-BUTYL N-DECYL PHTHALATE
117-81-7	1,2-BENZENEDICARBOXYLIC ACID, BIS(2-ETHYLHEXYL) ESTER
117-82-8	1,2-BENZENEDICARBOXYLIC ACID, BIS(2-METHOXYETHYL) ESTER
117-83-9	1,2-BENZENEDICARBOXYLIC ACID, BIS(2-BUTOXYETHYL) ESTER
117-84-0	1,2-BENZENEDICARBOXYLIC ACID, DIOCTYL ESTER
119-06-2	1,2-BENZENEDICARBOXYLIC ACID, DITRIDECYL ESTER
119-07-3	1,2-BENZENEDICARBOXYLIC ACID, DECYL OCTYL ESTER
131-11-3	1,2-BENZENEDICARBOXYLIC ACID, DIMETHYL ESTER
131-15-7	1,2-BENZENEDICARBOXYLIC ACID, BIS(1-METHYLHEPTYL) ESTER
131-17-9	1,2-BENZENEDICARBOXYLIC ACID, DI-2-PROPENYL ESTER
146-50-9	DIISOHEXYL PHTHALATE
3648-20-2	1,2-BENZENEDICARBOXYLIC ACID, DIUNDECYL ESTER
5334-09-8	PHTHALIC ACID, CYCLOHEXYL ISOBUTYL ESTER
25724-58-7	1,2-BENZENEDICARBOXYLIC ACID, DECYL HEXYL ESTER
26761-40-0	1,2-BENZENEDICARBOXYLIC ACID, DIISOOCTYL ESTER
27215-22-1	PHTHALIC ACID, BENZYL ISOOCTYL ESTER
27554-26-3	1,2-BENZENEDICARBOXYLIC ACID, DIISOOCTYL ESTER
28553-12-0	1,2-BENZENEDICARBOXYLIC ACID, DIISONONYL ESTER
61702-81-6	1,2-BENZENEDICARBOXYLIC ACID, HEXYL ISODECYL ESTER
61886-60-0	1,2-BENZENEDICARBOXYLIC ACID, ISODECYL TRIDECYL ESTER
ALKYLATED PHENOL SULFIDES	
90-66-4	PHENOL, 2,2'THIOBIS (6-(1,1-DIMETHYLETHYL)-4-METHYL
96-66-2	PHENOL, 4,4'-THIOBIS(2-(1,1-DIMETHYLETHYL)-6-METHYL
96-69-5	PHENOL, 4,4'THIOBIS (2-(1,1-DIMETHYLETHYL)-5-METHYL
3818-54-0	PHENOL, 4,4'-THIOBIS(3-(1,1-DIMETHYLETHYL)-5-METHYL
3120-74-9	PHENOL, 3-METHYL-4-(METHYLTHIO)
3294-03-9	PHENOL, 2,2'-THIOBIS(4-(1,1,3,3-TETRAMETHYLBUTYL)
7379-51-3	PHENOL, 3,5-DIMETHYL-4-(METHYLTHIO)
ALLYL CHLORIDE	
107-05-1	1-PROPENE, 3-CHLORO-
107-05-1	ALLYL CHLORIDE
ALUMINUM AND ALUMINUM COMPOUNDS	
UNKNOWN	ALUMINUM BIS (ACETYL SALICYLATE)
UNKNOWN	ALUMINUM CALCIUM HYDRIDE
UNKNOWN	DIISOBUTYL ALUMINUM HYDRIDE
97-93-8	ALUMINUM, TRIETHYL-
100-99-2	ALUMINUM, TRIS(2-METHYLPROPYL)-
139-12-8	ACETIC ACID, ALUMINUM SALT
142-03-0	ALUMINUM, BIS(ACETATO-O)HYDROXY-
555-31-7	2-PROPANOL, ALUMINUM SALT

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
555-35-1	HEXADECANOIC ACID, ALUMINUM SALT
555-75-9	ETHANOL, ALUMINUM SALT
688-37-9	ALUMINUM OLEATE
1318-16-7	BAUXITE
1327-36-2	ALUMINOSILICATE
1327-41-9	ALUMINUM CHLORIDE HYDROXIDE
1344-28-1	ALUMINUM OXIDE
7429-90-5	ALUMINUM
7446-70-0	ALUMINUM CHLORIDE
7784-18-1	ALUMINUM FLUORIDE
7784-21-6	ALUMINUM HYDRIDE
7784-25-0	SULFURIC ACID, ALUMINUM AMMONIUM SALT (2:1:1)
7784-26-1	SULFURIC ACID, ALUMINUM AMMONIUM SALT (2:1:1), DODECAHYDRATE
7784-30-7	PHOSPHORIC ACID, ALUMINUM SALT (1:1)
10043-01-3	SULFURIC ACID, ALUMINUM SALT (3:2)
10043-67-1	SULFURIC ACID, ALUMINUM POTASSIUM SALT (2:1:1)
10102-71-3	SULFURIC ACID, ALUMINUM SODIUM SALT (2:1:1)
11121-16-7	BORIC ACID, ALUMINUM SALT
12005-16-2	ALUMINATE, SODIUM
12005-48-0	ALUMINATE, SODIUM
12068-56-3	ALUMINUM OXIDE SILICATE
12656-43-8	ALUMINUM CARBIDE
13473-90-0	NITRIC ACID, ALUMINUM SALT
13771-22-7	ALUMINUM BOROHYDRIDE
15477-33-5	ALUMINUM CHLORATE
16853-85-3	ALUMINATE(1-), TETRAHYDRO-, LITHIUM, (T-4)-
18917-91-4	ALUMINUM, TRIS(2-HYDROXYPROPANOATO-01,02)-
21645-51-2	ALUMINUM HYDROXIDE
AMINOANTHRAQUINONE	
117-79-3	9,10-ANTHRACENEDIONE, 2-AMINO-
117-79-3	AMINOANTHRAQUINONE
AMINO-9-ETHYL CARBAZOLE	
132-32-1	9H-CARBAZOL-3-AMINE, 9-ETHYL-
132-32-1	AMINO-9-ETHYL CARBAZOLE
o-AMINOPHENOL	
95-55-6	o-AMINOPHENOL
67845-79-8	o-AMINOPHENOL SULFATE
51-19-4	o-AMINOPHENOL HYDROCHLORIDE
p-AMINOPHENOL	
123-30-8	p-AMINOPHENOL
51-78-5	p-AMINOPHENOL HCL
63084-98-0	p-AMINOPHENOL SO4
AMINOUNDECANOIC ACID	
2432-99-7	AMINOUNDECANOIC ACID
2432-99-7	UNDECANOIC ACID, 11-AMINO-
ANILINE	
62-53-3	ANILINE
62-53-3	BENZENAMINE
ANTIMONY TRIOXIDE	
1309-64-4	ANTIMONY OXIDE

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
AURAMINE	
492-80-8	AURAMINE
492-80-8	BENZENAMINE, 4,4'-CARBONIMIDOYLBISCN,N-DIMETHYL-
2465-27-2	BENZENAMINE, 4,4'-CARBONIMIDOYLBISCN,N-DIMETHYL-, MONOHYDROCHLO
AZOBENZENE	
103-33-3	AZOBENZENE
103-33-3	DIAZENE, DIPHENYL-
BENZAL CHLORIDE	
98-87-3	BENZAL CHLORIDE
98-87-3	BENZENE, (DICHLOROMETHYL)-
BENZOTRICHLORIDE	
98-07-7	BENZENE, (TRICHLOROMETHYL)-
98-07-7	BENZOTRICHLORIDE
BENZOYL CHLORIDE	
98-88-4	BENZOYL CHLORIDE
BENZYL ACETATE	
140-11-4	ACETIC ACID, PHENYLMETHYL ESTER
140-11-4	BENZYL ACETATE
BENZYL CHLORIDE	
100-44-7	BENZENE, (CHLOROMETYL)-
100-44-7	BENZYL CHLORIDE
BIPHENYL	
92-52-4	1,1'-BIPHENYL
BISPHENOL A	
80-05-7	BISPHENOL A
80-05-7	PHENOL, 4,4'-(1-METHYLETHYLIDENE)BIS-
BRILLIANT BLUE FCF	
2650-18-2	BENZENEMETHANAMINIUM, N-ETHYL-N-(4-((4- ETHYL((3-SULFOPHENYL)ME
2650-18-2	BRILLIANT BLUE FCF (DIAMMONIUM SALT)
3844-45-9	BENZENEMETHANAMINIUM, N-ETHYL-N-(4-((4- ETHYL((3-SULFOPHENYL)ME
3844-45-9	BRILLIANT BLUE FCF (DISODIUM SALT)
BROMINE AND BROMINE COMPOUNDS	
UNKNOWN	1,1,2,2-TETRABROMOPENTANE
74-83-9	METHANE, BROMO-
74-96-4	ETHANE, BROMO-
75-25-2	METHANE, TRIBROMO-
78-75-1	PROPANE, 1,2-DIBROMO-
96-12-8	PROPANE, 1,2-DIBROMO-3-CHLORO-
106-93-4	ETHANE, 1,2-DIBROMO-
107-04-0	ETHANE, 1,BROMO-2-CHLORO-
111-24-0	PENTANE, 1,5-DIBROMO-
557-91-5	ETHANE, 1,1-DIBROMO-
594-34-3	PROPANE, 1,2-DIBROMO-2-METHYL-
7926-95-6	BROMINE
BUTADIENE	
106-99-0	1,3-BUTADIENE
BUTANOL (ISO)	
78-83-1	1-PROPANOL, 2-METHYL-
78-83-1	BUTANOL (ISO)

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
BUTYL BENZALDEHYDE	
939-97-9	BENZALDEHYDE, 4-(1,1-DIMETHYLETHYL)-
939-97-9	BUTYL BENZALDEHYDE
BUTYL BENZOIC ACID	
98-73-7	BENZOIC ACID, 4-(1,1,-DIMETHYLETHYL)-
98-73-7	BUTYL BENZOIC ACID
BUTYL HYDROPEROXIDE	
75-91-2	BUTYL HYDROPEROXIDE
75-91-2	HYDROPEROXIDE, 1,1-DIMETHYLETHYL
BUTYLATED HYDROXYTOLUENE	
128-37-0	PHENOL,2,6-BIS (1,1-DIMETHYL ETHYL)-4-METHYL
128-37-0	BUTYLATED HYDROXYTOLUENE
BUTYL TOLUENE	
98-51-1	BENZENE, 1-(1,1-DIMETHYLETHYL)-4-METHYL-
98-51-1	BUTYL TOLUENE
C.I. DISPERSE YELLOW 3	
2832-40-8	ACETAMIDE, N-(4-((2-HYDROXY-5-METHYLPHENYL)AZO PHENYL)-
2832-40-8	DISPERSE YELLOW 3 (C.I.)
CARBON BLACK 1	
1333-86-4	CARBON BLACK
CARBON BLACK 2	
1333-86-4	CARBON BLACK
CARBON TETRACHLORIDE	
56-23-5	CARBON TETRACHLORIDE
56-23-5	METHANE, TETRACHLORO-
CHLORONITROBENZENE (2-)	
88-73-3	2-CHLORONITROBENZENE
CHLORONITROBENZENE (4-)	
100-00-5	4-CHLORONITROBENZENE
CHLOROBENZOTRICHLORIDE (4-)	
5216-25-1	BENZENE, 1-CHLORO-4-(TRICHLOROMETHYL)-
5216-25-1	CHLOROBENZOTRICHLORIDE
CHLORODIFLUOROMETHANE	
75-45-6	CHLORODIFLUOROMETHANE
75-45-6	METHANE, CHLORODIFLUORO-
CHLOROETHANE 1	
75-00-3	CHLOROETHANE
75-00-3	ETHANE, CHLORO-
CHLOROETHANE 2	
75-00-3	CHLOROETHENAE
75-00-3	ETHANE, CHLORO-
CHLOROETHYLENE	
75-01-4	CHLOROETHYLENE
75-01-4	ETHENE, CHLORO-
CHLOROHYDRIN (ALPHA)	
96-24-2	1,2-PROPANEDIOL, 3-CHLORO-
96-24-2	CHLOROHYDRIN (ALPHA)
CHLOROMETHANE	
74-87-3	CHLOROMETHANE
74-87-3	METHANE, CHLORO-
CHLORO METHYETHYL 1 ETHER (BIS)	
108-60-1	BIS(2-CHLORO-1-METHYETHYL) ETHER

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
COBALT NAPHTHENATE	
61789-51-3	COBALT NAPHTHENATE
61789-51-3	NAPTHENIC ACIDS, COBALT SALTS
CUMENE HYDROPEROXIDE	
80-15-9	CUMENE HYDROPEROXIDE
80-15-9	HYDROPEROXIDE, 1-METHYL-1-PHENYLETHYL
CUTTING FLUIDS	
NONE	CUTTING FLUIDS
CYANURIC ACID AND CHLORINATED DERIVATIVES	
87-90-1	1,3,5-TRIAZINE-2,4,6(1H,3H,5H)-TRIONE, 1,3,5-TRICHLORO-
108-80-5	1,3,5-TRIAZINE-2,4,6(1H,3H,5H)-TRIONE
108-80-5	CYANURIC ACID
2244-21-5	1,3,5-TRIAZINE-2,4,6(1H,3H,5H)-TRIONE, 1,3-DICHLORO-, POTASSIUM
2624-17-1	MONOSODIUM CYANURATE
2782-57-2	1,3,5-TRIAZINE-2,4,6(1H,3H,5H)-TRIONE, 1-3-DICHLORO-
2893-78-9	1,3,5-TRIAZINE-2,4,6(1H,3H,5H)-TRIONE, 1-3-DICHLORO-, SODIUM SA
CYCLOHEXYLAMINE	
101-83-7	CYCLOHEXANAMINE, N-CYCLOHEXYL-
108-91-8	CYCLOHEXANAMINE
108-91-8	CYCLOHEXYLAMINE
947-92-2	2-NITROSODOCYCLOHEXYL
947-92-2	N-NITROSODICYCLOHEXYL
3129-92-8	BENZOIC ACID, COMPD, WITH CYCLOHEXANAMINE (1:1)
3882-06-2	DICYCLOHEXYLAMINE NITRATES
5473-16-5	3,5-DINITRO
20227-92-3	CARBONATE
20736-64-5	CHROMATE
34067-50-0	4-NITROBENZOATE
34139-62-3	3-NITROBENZOATE
D AND C RED #9	
5160-02-1	BENZENESULFONIC ACID, 5-CHLORO-2-((2-HYDROXY-1-NAPHTHALENYL)AZO
5160-02-1	D AND C RED #9
DIAMINOAZOBENZENE (2,4-)	
495-54-5	2,4-DIAMINOAZOBENZENE
532-82-1	2,4-DIAMINOAZOBENZENEHYDROCHLORIDE
DIAMINOBIPHENYL ETHER 1	
101-80-4	BENZENAMINE, 4,4'-OXYBIS-
101-80-4	DIAMINOBIPHENYL ETHER
DIAMINOBIPHENYL ETHER 2	
101-80-4	BENZENAMINE, 4,4'-OXYBIS-
101-80-4	DIAMINOBIPHENYL ETHER
DIAMINOHEXANE	
124-09-4	1,6-HEXANEDIAMINE
124-09-4	DIAMINOHEXANE
DIAZABICYCLOOCTANE	
280-57-9	1,4-DIAZABICYCLO(2,2,2)Octane
DIBROMOETHANE	
106-93-4	DIBROMOETHANE
106-93-4	ETHANE, 1,2-DIBROMO-

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
DICHLOROACETALDEHYDE	
79-02-7	ACETALDEHYDE, DICHLORO-
79-02-7	DICHLOROACETALDEHYDE
DICHLOROETHANE	
107-06-2	DICHLOROETHANE
107-06-2	ETHANE, 1,2-DICHLORO-
DICHLOROMETHANE	
75-09-2	DICHLOROMETHANE
75-09-2	METHANE, DICHLORO-
DICHLORO DIOXANE	
95-59-0	2,3-DICHLORO - 1,4-DIOXANE
3883-43-0	
DICHLOROPROPANE	
142-28-9	DICHLOROPROPANE
142-28-9	PROPANE, 1,3-DICHLORO-
DIETHYLENE GLYCOL	
111-46-6	DIETHYLENE GLYCOL
111-46-6	ETHANOL, 2,2'-OXYBIS-
DIETHYLHEXYL ADIPATE	
103-23-1	HEXANEDIOIC ACID, BIS(2-ETHYLHEXYL)ESTER
103-23-1	DIETHYLHEXYL ADIPATE
DIETHYLPHOSPHOROCHLOROTHIOATE	
2524-04-1	DIETHYLPHOSPHOROCHLOROTHIOATE
2524-04-1	PHOSPHOROCHLORIDOTHIOIC ACID, O,O-DIETHYL ESTER
DIHYDROSAFROLE	
94-58-6	1, 3-BENZODIOXOLE, 5-PROPYL
94-58-6	DIHYDROSAFROLE
DIMETHOXANE 1	
828-00-2	1,3-DIOXAN-4-OL, 2,6-DIMETHYL-, ACETATE
828-00-2	DIMETHOXANE
DIMETHOXANE 2	
828-00-2	1,3-DIOXAN-4-OL, 2,6-DIMETHYL-, ACETATE
828-00-2	DIMETHOXANE
DIMETHYLFORMAMIDE I	
68-12-2	DIMETHYLFORMAMIDE
68-12-2	FORMAMIDE, N,N-DIMETHYL-
DIMETHYLFORMAMIDE 2	
68-12-2	DIMETHYLFORMAMIDE
68-12-2	FORMAMIDE, N,N-DIMETHYL-
DIMETHYL METHYLPHOSPHONATE	
756-79-6	DIMETHYL METHYLPHOSPHONATE
DIMETHYLPHOSPHOROCHLOROTHIOATE	
2524-03-0	DIMETHYLPHOSPHOROCHLOROTHIOATE
2524-03-0	PHOSPHOROCHLORIDOTHIOIC ACID, O,O-DIMETHYL ESTER
DIMETHYLTHIOUREA	
534-13-4	DIMETHYLTHIOUREA
534-13-4	THIOUREA, N,N'-DIMETHYL-
DINITROCHLOROBENZENE	
97-00-7	BENZENE, 1-CHLORO-2,4-DINITRO-
97-00-7	DINITROCHLOROBENZENE

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
DINITROPHENOL	
51-28-5	DINITROPHENOL
51-28-5	PHENOL, 2,4-DINITRO-
DINITROSOPENTAMETHYLENETETRAMINE	
101-25-7	1,3,5,7-TETRAAZABICYCLO(3,3,1)NONANE, 3,7-DINITROSO-
101-25-7	DINITROSOPENTAMETHYLENETETRAMINE
DINITROTOLUENE	
121-14-2	BENZENE, 1-METHYL-2,4-DINITRO-
121-14-2	DINITROTOLUENE
DIOXANE	
123-91-1	1,4-DIOXANE
EPOXY/CHLOROHYDROXY PROPYL TRIMETHYLAMMONIUM CHLORIDE	
3033-77-0	EPOXY TRIMETHYLAMMONIUM CHLORIDE
3327-22-8	CHLOROHYDROXYPROPYL TRIMETHYL AMMONIUM CHLORIDE
ETHANOLAMINES	
NONE	ETHANOLAMINES
102-71-6	ETHANOL, 2,2',2''-NITRILOTRIS-
111-42-2	ETHANOL, 2,2'-IMINOBIS-
141-43-5	ETHANOL, 2-AMINO-
ETHOXYETHANOL	
110-80-5	ETHANOL, 2-ETHOXY-
110-80-5	ETHOXYETHANOL
ETHOXYETHANOL ACETATE	
111-15-9	ETHANOL, 2-ETHOXY-, ACETATE
111-15-9	ETHOXYETHANOL ACETATE
ETHYL ACRYLATE	
140-88-5	2-PROPENOIC ACID, ETHYL ESTER
140-88-5	ETHYL ACRYLATE
ETHYLAMINES	
NONE	ETHYLAMINES
75-04-7	ETHYLAMINE
109-89-7	ETHYLAMINE, N-ETHYL-
121-44-8	ETHYLAMINE, N,N-DIETHYL-
ETHYLENE OXIDE	
75-21-8	ETHYLENE OXIDE
75-21-8	OXIRANE
ETHYLENEDIAMINE	
107-15-3	1,2-ETHANEDIAMINE
107-15-3	ETHYLENEDIAMINE
ETHYLENEDIAMINETETRA (METHYLENE PHOSPHORIC ACID)	
1429-50-1	ETHYLENEDIAMINE TETRA (METHYLENE PHOSPHONIC ACID)
68188-96-5	ETHYLENEDIAMINETETRA (METHYLENE PHOSPHORIC ACID)
15142-96-9	ETHYLENEDIAMINETETRA (METHYLENE PHOSPHORIC ACID) HEXASODIUM SALT
ETHYLHEXYL ACRYLATE	
103-11-7	2-PROPENOIC ACID, 2-ETHYLHEXYL ESTER
103-11-7	ETHYLHEXYL ACRYLATE
FORMALDEHYDE	
50-00-0	FORMALDEHYDE

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
FORMAMIDE	
75-12-7	FORMAMIDE
GENTIAN VIOLET	
548-62-9	GENTIAN VIOLET
548-62-9	METHANAMINIUM, N-(4-(BIS(4-(DIMETHYLAMINO)PHENYL)METHYLENE)-2,5
HEXACHLOROCYCLOPENTADIENE	
77-47-4	1,3-CYCLOPENTADIENE, 1,2,3,4,5,5-HEXACHLORO-
77-47-4	HEXACHLOROCYCLOPENTADIENE
HEXACHLOROETHANE	
67-72-1	ETHANE, HEXACHLORO-
67-72-1	HEXACHLOROETHANE
HEXACHLORONORBORNADIENE	
3389-71-7	1,2,3,4,7,7-HEXACHLORONORBORNADIENE
HEXAFLUOROACETONE	
684-16-2	2-PROPANONE, 1,1,1,3,3,3-HEXAFLUORO-
684-16-2	HEXAFLUOROACETONE
HEXAMETHYLPHOSPHORAMIDE	
680-31-9	HEXAMETHYLPHOSPHORAMIDE
680-31-9	PHOSPHORIC TRIAMIDE, HEXAMETHYL-
HEXAMETHYLPHOSPHORAMIDE 2	
680-31-9	HEXAMETHYLPHOSPHORAMIDE
680-31-9	PHOSPHORIC TRIAMIDE, HEXAMETHYL-
HEXANE	
110-54-3	HEXANE
HIGH EXPLOSIVE	
CONFIDENT	CONFIDENTIAL
NONE	HIGH EXPLOSIVE
HYDRAZOBENZENE	
122-66-7	HYDRAZINE, 1,2-DIPHENYL-
122-66-7	HYDRAZOBENZENE
ISOBUTYL ALCOHOL	
78-83-1	ISOBUTANOL
ISOPROPYL ALCOHOL 1	
67-63-0	2-PROPANOL
67-63-0	ISOPROPYL ALCOHOL
ISOPROPYL ALCOHOL 2	
67-63-0	2-PROPANOL
67-63-0	ISOPROPYL ALCOHOL
LITHIUM AND LITHIUM COMPOUNDS	
546-89-4	ACETIC ACID, LITHIUM SALT
554-13-2	CARBONIC ACID, DILITHIUM SALT
556-63-8	FORMIC ACID, LITHIUM SALT
1310-65-2	LITHIUM HYDROXIDE
7439-93-2	LITHIUM
7447-41-8	LITHIUM CHLORIDE
7550-35-8	LITHIUM BROMIDE
7580-67-8	LITHIUM HYDRIDE
7782-89-0	LITHIUM AMIDE
7789-24-4	LITHIUM FLUORIDE

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
7790-69-4	NITRIC ACID, LITHIUM SALT
10102-24-6	SILICIC ACID, DILITHIUM SALT
10377-51-2	LITHIUM IODIDE
12007-60-2	BORIC ACID, DILITHIUM SALT
12057-24-8	LITHIUM OXIDE
13453-69-5	BORIC ACID, LITHIUM SALT
16853-85-3	ALUMINATE(1-), TETRAHYDRO-, LITHIUM, (T-4)-
MALEIC ANHYDRIDE 1	
108-31-6	2,5-FURANDIONE
108-31-6	MALEIC ANHYDRIDE
MALEIC ANHYDRIDE 2	
108-31-6	2,5-FURANDIONE
108-31-6	MALEIC ANHYDRIDE
MELAMINE	
108-78-1	1,3,5-TRIAZINE-2,4,6-TRIAMINE
108-78-1	MELAMINE
MERCAPTOBENZOTHIAZOLE DISULFIDE	
120-78-5	BENZOTHIAZOLE, 2,2'-DITHIOBIS-
120-78-5	DITHIOBISBENZOTHIAZOLE (2,2-)
METHANOL	
67-56-1	METHANOL
METHOXYETHANOL	
109-86-4	ETHANOL, 2-METHOXY-
109-86-4	METHOXYETHANOL
METHOXYETHANOL ACETATE	
110-49-6	ETHANOL, 2-METHOXY-, ACETATE
110-49-6	METHOXYETHANOL ACETATE
METHYLCYCLOPENTADIENYL MANGANESE TRICARBONYL	
12108-13-3	
METHYL ETHYL KETONE PEROXIDE	
1338-23-4	2-BUTANONE, PEROXIDE
1338-23-4	METHYL ETHYL KETONE PEROXIDE
METHYL N-AMYL KETONE	
110-43-0	2-HEPTANONE
110-43-0	METHYL N-AMYL KETONE
METHYL N-BUTYL KETONE	
591-78-6	2-HEXANONE
591-78-6	METHYL N-BUTYL KETONE
METHYLNITROPROPYL-4-NITROSOANILINE	
24458-48-8	MNNA
METHYLAMINES	
NONE	METHYLAMINES
74-89-5	METHANAMINE
75-50-3	METHANAMINE, N,N-DIMETHYL-
124-40-3	METHANAMINE, N-METHYL-
METHYLCYCLOHEXANE	
108-87-2	CYCLOHEXANE, METHYL-
108-87-2	METHYLCYCLOHEXANE

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
METHYLENE BIS (2-CHLOROANILINE)	
101-14-4	BENZENEAMINE, 4,4'-METHYLENEBIS(2-CHLORO-
101-14-4	METHYLENE BIS (2-CHLOROANILINE)
101-14-4	MOCA
METHYLENE DIPHENYLDIISOCYANATE	
101-68-8	METHYLENE DIPHENYLDIISOCYANATE
101-68-8	BENZENE, 1,1'-METHYLENEBIS(4-ISOCYANATO-
9016-87-9	ISOCYANIC ACID, POLYMETHYLENEPOLYPHENYLENE ISTER
26447-40-5	BENZENE, 1,1'-METHYLENE BIS (ISOCYANATO-
METHYLENEBIS(N,N-DIMETHYL)-BENZENAMINE	
101-61-1	BENZENAMINE, 4,4'-METHYLENEBIS(N,N-DIMETHYL-
101-61-1	METHYLENEBIX(N,N-DIMETHYL)-BENZENAMINE
METHYLPYRIDINE (2-)	
109-06-8	METHYLPYRIDINE (2-)
109-06-8	PYRIDINE, 2-METHYL-
METHYLPYRIDINE (3-)	
108-99-6	METHYLPYRIDINE (3-)
108-99-6	PYRIDINE, 3-METHYL-
METHYLPYRIDINE (4-)	
108-89-4	METHYLPYRIDINE (4-)
108-89-4	PYRIDINE, 4-METHYL-
MONO/DICHLOROPHENOLS	
UNKNOWN	2-5-DICHLOROPHENOL
UNKNOWN	3-4-DICHLOROPHENOL
UNKNOWN	3-5-DICHLOROPHENOL
NONE	MONO/DICHLOROPHENOLS
87-65-0	PHENOL, 2,6-DICHLORO-
95-57-8	PHENOL, 2-CHLORO-
106-48-9	PHENOL, 4-CHOLRO-
108-43-0	PHENOL, 3-CHLORO-
120-83-2	PHENOL, 2,4-DICHLORO-
576-24-9	PHENOL, 2,3-DICHLORO-
MORPHOLINE	
110-91-8	MORPHOLINE
NAPTHA (PETROLEUM) SOLVENTS	
64741-66-8	NAPTHA (PETROLEUM), LIGHT AKLYLATE
64742-88-7	SOLVENT NAPTHA (PETROLEUM), MEDIUM ALIPHATIC
NEOPENTYL GLYCOL DIACRYLATE	
2223-82-7	2-PROPENOIC ACID, 2,2,-DIMETHYL-1,3-PROPANEDIYL ESTER
2223-82-7	NEOPENTYL GLYCOL DIACRYLATE
NEOPENTYL GLYCOL DIGLYCIDYL ETHER	(70 WT% OF HELOXY WC-68)
17557-23-2	NEOPENTYL GLYCOL DIGLYCIDYL ETHER
17557-23-2	OXIRANE, 2,2'- (2,2-DIMETHYL-1,3-PROPANEDIYL)BIS(OXYMETHYLENE)
NITRO-O-ANISIDINE	
99-59-2	BENZENAMINE, 2-METHOXY-5-NITRO-
99-59-2	NITRO-O-ANISIDINE
NITRO-O-TOLUIDINE	
99-55-8	BENZENAMINE, 2-METHYL-5-NITRO-
99-55-8	NITRO-O-TOLUIDINE

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
NITROBENZENE	
98-95-3	BENZENE, NITRO-
98-95-3	NITROBENZENE
NITROPROPANE	
79-46-9	NITROPROPANE
79-46-9	PROPANE, 2-NITRO,
NITROSO COMPOUNDS	
UNKNOWN	DIBENZYLNITROSAMINE
UNKNOWN	DICYCLOHEXYLNITROSAMINE
UNKNOWN	METHYLBENZYLNITROSAMINE
UNKNOWN	METHYLCYCLOHEXYLNITROSAMINE
NONE	NITROSO COMPOUNDS
UNKNOWN	NITROSOMORPHOLINE
55-18-5	ETHANAMINE, N-ETHYL-N-NITROSO-
62-75-9	METHANAMINE, N-METHYL-N-NITROSO-
86-30-6	BENZENAMINE, N-NITROSO-N-PHENYL-
100-75-4	PIPERIDINE, 1-NITROSO-
614-00-6	BENZENAMINE, N-METHYL-N-NITROSO-
621-64-7	1-PROPANAMINE, N-NITROSO-N-PROPYL
684-93-5	UREA, N-METHYL-N-NITROSO-
759-73-9	UREA, N-ETHYL-N-NITROSO-
930-55-2	PYRROLIDINE, 1-NITROSO-
1116-54-7	ETHANOL, 2,2'-(NITROSOIMINO)BIS-
53609-64-6	NITROSODIISOPROPANOLAMINE
NITROSODIPHENYLAMINE	
86-30-6	BENZENAMINE, N-NITROSO-N-PHENYL-
86-30-6	NITROSODIPHENYLAMINE
OXYBIS(2-METHOXY)ETHANE	
111-96-6	BIS(2-METHOXY)ETHER
111-96-6	ETHANE, 1,1'-OXYBIS 2-METHOXY-
111-96-6	OXYBIS(2-METHOXY)ETHANE
PENTABROMOCHLOROCYCLOHEXANE	
87-84-3	CYCLOHEXANE, 1,2,3,4,5-PENTABROMO-6-CHLORO-
87-84-3	PENTABROMOCHLOROCYCLOHEXANE
PENTACHLOROETHANE	
76-01-7	ETHANE, PENTACHLORO-
76-01-7	PENTACHLOROETHANE
PENTANONE	
107-87-9	2-PENTANONE
PHENYL GLYCIDYL ETHER	
122-60-1	OXIRANE, (PHENOXYMETHYL)-
122-60-1	PHENYL GLYCIDYL ETHER
PHENYLENEDIAMINES	
NONE	PHENYLENEDIAMINES
95-54-5	1,2-BENZENEDIAMINE
106-50-3	1,4-BENZENEDIAMINE
108-45-2	1,3-BENZENEDIAMINE
PHOSGENE	
75-44-5	CARBONIC DICHLORIDE
75-44-5	PHOSGENE

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
POLYSORBATE 20	
9005-64-5	POLYSORBATE 20
9005-64-5	SORBITAN, MONODODECANDATE, POLY(OXY-1,2-ETHANEDIYL) DERIVS,
n-PROPYL ALCOHOL	
71-23-8	1-PROPANOL
PROPIONITRILE	
107-12-0	PROPANENITRILE
107-12-0	PROPYLNITRILE
QUARTZ, SILICA, CRYSTALLINE	
14808-60-7	QUARTZ
QUINOLINE	
91-22-5	BENZO(B)PYRIDINE
RHODAMINE B	
81-88-9	ETHANAMINIUM, N-(9-(2-CARBOXYPHENYL)-6-(DIETHYLAMINO)-3H-XANTHE
81-88-9	RHODAMINE B
SEMICARBAZIDE	
57-56-7	HYDRAZINECARBOXAMIDE
57-56-7	SEMICARBAZIDE
SODIUM AZIDE	
26628-22-8	SODIUM AZIDE
STYRENE OXIDE	
96-09-3	OXIRANE, PHENYL-
96-09-3	STYRENE OXIDE
SULFOLANE	
126-33-0	SULFOLANE
126-33-0	THIOPHENE, TRETAHYDRO, 1,1-DIOXIDE
SULFUR HEXAFLUORIDE	
2551-62-4	SULFUR FLUORIDE, (OC-6-11)-
2551-62-4	SULFUR HEXAFLUORIDE
TELLURIUM 1	
13494-80-9	TELLURIUM
TELLURIUM 2	
13494-80-9	TELLURIUM
TEREPHTHALIC ACID	
100-21-0	1,4-BENZENEDICARBOXYLIC ACID
100-21-0	TEREPHTHALIC ACID
TETRABROMOETHANE	
79-27-6	ETHANE, 1,1,2,2-TETRABROMO-
79-27-6	TETRABROMOETHANE
TETRACHLOROETHANE	
79-34-5	ETHANE, 1,1,2,2-TETRACHLORO-
TETRACHLORO-1-PROPENE	
10436-39-2	1-PROPENE, 1,1,2,3-TETRACHLORO
10436-39-2	1,1,2,3-TETRACHLOROPROPENE
TETRAHYDROFURAN 1	
109-99-9	FURAN, TETRAHYDRO-
109-99-9	TETRAHYDROFURAN
TETRAHYDROFURAN 2	
109-99-9	FURAN, TETRAYDRDO-
109-99-9	TETRAHYDROFURAN

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
TETRAMETHYLSUCCINONITRILE	
3333-52-6	TETRAMETHYLSUCCINONITRILE
THIOUREA	
62-56-6	THIOUREA
THORIUM DIOXIDE	
1314-20-1	THORIUM OXIDE
TMOHS (SILANE A-186)	
3388-04-3	SILANE, TRIMETHOXY(2-(7-OXABICYCLO(4,1,0)HEPT-3-YL)ETHYL)-
3388-04-3	TMOHS (SILANE A-186)
TOLUENE	
108-88-3	BENZENE, METHYL-
108-88-3	TOLUENE
TOLUENE DIISOCYANATE	
1321-38-6	TOLUENEDIISOCYANATE
584-84-9	2,4-TOLUENE DIISOCYANATE
91-08-7	2,6-TOLUENE DIISOCYANATE
26471-62-5	2,4 & 2,6-TOLUENEDIISOCYANATE (Mixed Isomer)
TOLUENE-2,4-DIAMINE	
95-80-7	1,3-BENZENEDIAMINE, 4-METHYL-
95-80-7	TOLUENE-2,4-DIAMINE
ortho-TOLUIDINE	
95-53-4	ortho-TOLUIDINE
636-21-5	ortho-TOLUIDINE HYDROCHLORIDE
TRIBROMOPHENOL	
118-79-6	PHENOL, 2,4,6-TRIBROMO-
118-79-6	TRIBROMOPHENOL
TRICHLOROACETALDEHYDE	
75-87-6	ACETALDEHYDE, TRICHLORO-
75-87-6	TRICHLOROACETALDEHYDE
302-17-0	1,1-ETHANEDIOL, 2,2,2-TRICHLORO-
TRICHLOROBUTYLENE OXIDE	
3083-25-8	OXIRANE, (2,2,2-TRICHLOROETHYL)-
3083-25-8	TRICHLOROBUTYLENE OXIDE
TRICHLOROETHANE	
79-00-5	ETHANE, 1,1,2-TRICHLORO-
79-00-5	TRICHLOROETHANE
TRIETHANOLAMINE	
102-71-6	ETHANOL, 2,2',2''-NITRILOTRIS-
102-71-6	TRIETHANOLAMINE
TRIETHYLENE TETRAMINE	
112-24-3	1,2-ETHANEDIAMINE, N,N'-BIS(2-AMINOETHYL)-
112-24-3	TRIETHYLENE TETRAMINE
TRIMELLITIC ANHYDRIDE	
552-30-7	5-ISOBENZOFURANCARBOXYLIC ACID, 1-3-DIHYDRO-1,3-DIOXO-
552-30-7	TRIMELLITIC ANHYDRIDE
TRIMETHYL PHOSPHITE	
121-45-9	PHOSPHOROUS ACID, TRIMETHYL ESTER
121-45-9	TRIMETHYL PHOSPHITE
TRINITROFLUORENONE	
129-79-3	9H-FLUOREN-9-ONE, 2,4,7-TRINITRO-
129-79-3	TRINITROFLUORENONE

SUBJECT OF CHIP AND CAS NO.	CHEMICAL NAME OF CHEMICALS MENTIONED IN CHIP
TRINITROTOLUENE	
118-96-7	BENZENE, 2-METHYL-1,3,5-TRINITRO-
118-96-7	TRINITROTOLUENE
TRIOCTYLAMINE	
1116-76-3	1-OCTANAMINE, N,N-DIOCTYL-
1116-76-3	TRIOCTYLAMINE
TRIS (1,3-DICHLORO-2-PROPANOL) PHOSPHATE	
13674-87-8	2-PROPANOL, 1,3-DICHLORO-, PHOSPHATE (3:1)
13674-87-8	FYROL FR-2
URETHANE	
51-79-6	CARBAMIC ACID, ETHYL ESTER
51-79-6	URETHANE
VERMICULITE	
1318-00-9	VERMICULITE
VINYL ACETATE	
108-05-4	ACETIC ACID ETHENYL ESTER
108-05-4	VINYL ACETATE
VINYL BROMIDE	
593-60-2	ETHENE, BROMO
593-60-2	VINYL BROMIDE
VINYL FLUORIDE	
75-02-5	ETHENE, FLUORO-
75-02-5	VINYL FLUORIDE
VINYL-1-CYCLOHEXENE	
100-40-3	CYCLOHEXENE, 4-ETHENYL-
100-40-3	VINYL-1-CYCLOHEXENE
VINYLIDENE BROMIDE	
593-92-0	VINYLIDENE BROMIDE
VINYLIDENE FLUORIDE	
75-38-7	ETHENE, 1,1-DIFLUORO
75-38-7	VINYLIDENE FLUORIDE
ZIRAM	
137-30-4	ZINC, BIS(DIMETHYLCARBAMODITHIOATO-S,S)-(T-4)-,(9CI)

APPENDIX A.3

COMMON SYNONYMS FOR POTENTIAL HAP'S

Reference: State of Maine Department of Environmental Protection
Bureau of Air Quality Control

ALPHABETICAL LIST OF SUSPECTED HAZARDOUS AIR POLLUTANTS

SUBSTANCE	CAS REGISTRY #	COMMON SYNONYMS *
Acetaldehyde	75-07-0	Ethanal, Ethyl aldehyde, Acetic aldehyde
Acetamide	60-35-5	Acetic acid amide, Ethanamide, Methanecarboxamide
Acetic anhydride	108-24-7	Acetic oxide, acetyloxide
Acetone	67-64-1	Dimethylformaldehyde, Dimethyl ketone, Ketopropane, Propanone,Pyroacetic acid
2-Acetylaminofluorene	53-96-3	n-Fluoren-2-Ylacetamide, AAF
Acrolein	107-02-8	2-Propenal, Acrylic aldehyde, Acrylaldehyde, Acraldehyde
Acrylamide	79-06-1	Ethylenecarboxamide, Propenamide
Acrylic acid	79-10-7	Ethylenecarboxylic acid, Propene acid, Propenoic acid, Vinylformic acid
Acrylic acid, Ethyl ester	140-88-5	Ethoxycarbonylethylene, Ethyl acrylate, Ethyl propenoate, 2-Propenoic acid ethyl ester
Acrylonitrile	107-13-1	Cyanoethylene, Fumigrain, Ventox, Propenenitrile, Vinyl cyanide, VCN, TL 314, ENT 54, Miller's fumigrain
Aldicarb	116-06-3	ENT 27093, OMS-771, Temic, NCI-C08640, Union Carbide 21149
Allyl chloride	107-05-1	3-Chloropropene, Chlorallyene, 3-Chloropropylene
Alpha benzene hexachloride	319-84-6	alpha-Hexachlorcyclohexane, alpha-BHC, alpha-HCH, ENT 9232, alpha-Lindane, alpha-Hexachloran
p-Aminodiphenyl	92-67-1	4-Aminobiphenyl, Biphenylamine, Paraminodiphenyl, Xenylamine
Aniline and salts	62-53-3	Aminobenzene, Aminophen, Blue oil, Cyanol, Phenylamine
p-Anisidine	104-94-9	Anisole p-amino, 4-Methoxybenzenamine, p-Methoxyaniline
Antimony (dust and salts) as Sb	7440-36-0	C.I. 77050, Stibium
Arsine	7784-42-1	Arseniuretted hydrogen, Arsenic hydride

*NOTE: NOT all synonyms and trade names are listed. If you are unsure whether your company uses any of these substances, please call the Bureau of Air Quality Control (289-2437), for assistance.

SUBSTANCE	CAS REGISTRY #	COMMON SYNONYMS
Arsenic (dust and salts) as As	7440-38-2	
Asbestos	1332-21-4	
Auramine (technical grade)	2465-27-2	C.I. Basic yellow, C.I. 4100
Barium (dust and salts) as Ba	7440-39-3	
Benzene	71-43-2	Cyclohexatriene, Benzol, Pirobenzol
Benzidine	92-87-5	Fast corinth base B, C.I. Azoic diazo, Component 112, 4,4'-Diphenylenediamine
Benzo(a)pyrene	50-32-8	BP, B(a)P
Benzotrichloride	98-07-07	Toluene alpha,alpha,alpha trichloro-, Phenyl chloroform, Trichloromethylbenzene
Benzyl chloride	100-44-7	Toluene alpha-chloro-, Chloromethylbenzene, Chlorophenylmethane, NCI-C06360, Tolyl chloride
Beryllium (dust and salts) as Be	7440-41-7	
Beta-Propiolactone	57-57-8	2-Oxetanone, Betaprone, BPL, Hydroacrylic acid, Beta Lactone
Biphenyl	92-52-4	Bibenzene, Diphenyl, Lemonene, Phenador-X, PHPH, Phenylbenzene, Xenene
Bis(chloromethyl) ether	542-88-1	sym-Dichloromethyl ether, Oxybis (Chloromethane), BCME
Bis(2-ethylhexyl) phthalate	117-81-7	Celluflex DOP, Dinopol NOP, Dioctyl phthalate, Octyl phthalate, Polycizer 162, PX-138, Vinicizer 85, Phthalic acid dioctyl ester
Bromine	7726-95-6	
1,3,-Butadiene	106-99-0	Biethylene, Bivinyl, Divinyl, Erythrene, NCI-C50602, Pyrrolylene, Vinylethylene
Butanethiol	109-79-5	Butyl mercaptan, NCI-C60866
Butanol (n-Butyl Alcohol)	71-36-3	Butyl hydroxide, Butyricalcohol, Normal primarybutyl alcohol, CCS203, 1-Hydroxybutane, Methylolpropane, Propylcarbinol, Propyl methanol
n-Butyl acetate	123-86-4	Acetic acid butyl ester, Butyl ethanoate
n-Butylamine	109-73-9	1-Aminobutane, 1-Butanamine, Norvalamine
Cadmium (dust and salts) as Cd	7440-43-9	C.I. 77180
Carbon Tetrachloride	56-23-5	Benzinoform, Carbona, ENT 4705, Fasciolin, Halon 104, Perchloromethane, Tetrachloromethane
Carbon disulfide	75-15-0	NCI-C04591, Sulphocarbonic anhydride, Weeviltox
Chlorine	7782-50-5	
Chlorine dioxide	10049-04-4	Chlorine oxide, Chlorine peroxide

SUBSTANCE	CAS REGISTRY #	COMMON SYNONYMS
Chloroacetophenone(2-) (Phenacylchloride)	532-27-4	CAF, CAP, Chloromethyl phenyl ketone, Phenacyl chloride, Mace(lacrimator)
p-Chloroaniline	106-47-8	4-Chlorophenylamine, NCI-C02039
Chloroform	67-66-3	Formyl trichloride, Freon 20, Methane trichloride, NCI-C02686, R 20, Trichloromethane
Chloromethyl methyl ether	107-30-2	CMME, Dimethylchloroether
p-Chloronitrobenzene	100-00-5	1-Chloro-4-nitro-benzene,
Chloroprene	126-99-8	1,3-Butadiene, 2-chloro-, Neoprene
Chromium (VI) insoluble compounds	7440-47-3	Chrome
Chrysene	218-01-9	1,2,5,6-Dibenzonaphthalene, 1,2-Benzophenanthrene
Cobalt (dust and salts) as Co	7440-48-4	C.I. 77320, NCI-C60311
Copper (fumes, dusts & mists) as Cu	7440-50-8	Bronze powder, C.I.77400, C.I. pigment metal, 1721 Gold, Gold bronze, Copper bronze
Cresol (all isomers)	1319-77-3	Cresylic acid
Cyanimide	420-04-2	Amidocyanogen, Carbamonitrile, Carbimide, Cyanogen nitride, USAF EK-1995
Cyanic acid (K salt)	590-28-3	Crabgrass killer, Potassium Cyanate, Alicyanate
Cyanic acid (Na salt)	917-61-3	Cyansan, San-Cyan, Weecon, Zassol
Cyanides (as Cn)	57-12-5	
Cyanoacetamide	107-91-5	CAA, Malonamonitrile, USAF KF-14
Cyanogen	460-19-5	Dicyan, Ethanedinitrile, Oxalonitrile
Cyclohexane	110-82-7	Hexahydrobenzene, Hexamethylene, Hexanaphthene
2,5-Diaminotoluene	95-70-5	C.I. 76042, 2-Methyl-1,4-Benzenediamine, 2-Methyl-p-Phenylenediamine
Diazomethane	334-88-3	Azimethylene
1,2-Dichlorethane	107-06-2	Borer sol, Brocide, Destruxol borer sol, Dichloroethylene, EDC, Dutch oil, ENT 1656, Freon 150, Glycol dichloride, NCI-C00511
1,2-Dichlorobenzene	95-50-1	Chloroben, DCB, Dilatin, DB, Dizene, Dowtherm E, NCI-C54944, ODB, ODCB, Orthodichlorobenzene, Special termite fluid, Termitkil
1,2-Dichloropropane	78-87-5	ENT 15,406, NCI-C55141, Propylene Chloride, Propylene Dichloride

SUBSTANCE	CAS REGISTRY #	COMMON SYNONYMS
3,3-Dichlorobenzidine	91-94-1	4,4'-Diamino-3,3'-Dichlorobiphenyl, C.I.-23060, DCB
Diethyl phthalate	84-66-2	Phthalic acid diethyl ester, Anozol, 1,2-Benzenedicarboxylic acid diethyl ester, Ethyl phthalate, NCI-C60048, Neatine, Palatinol A, Phthalol, Placidol E, Solvanol
Diethyl sulfate	64-67-5	Sulfuric acid diethyl ester, DS, Ethyl sulfate
Diisoctyl phthalate	27554-26-3	
Diisodecyl phthalate	26761-40-0	
3,3-Dimethoxybenzidine (o-dianisidine)	119-90-4	Acetamine diazo black and navy rd, Azoene fast blue base and salt, C.I. Azoic diazo component 48 fast blue B salt, Spectrolene blue B
1,1-Dimethyl hydrazine	57-14-7	Diamazine, Unsymmetrical dimethylhydrazine, UDMH
Dimethyl sulfate	77-78-1	Sulfuric acid dimethyl ester, Dimethyl monosulfate, DMS (methyl sulfate)
Dimethylaminoazobenzene	60-11-7	Atul fast yellow, Waxoline yellow ads
Dimethylcarbamyl chloride	79-44-7	Chloroformic acid dimethylamide, DDC, DMCC, TL 389
m-Dinitrobenzene	99-65-0	
1,4-Dioxane	123-91-1	Diethylene dioxide, Diethylene ether, Dioxethylene ether, Glycol ethylene ether, NCI-C03689,Tetrahydro- p-dioxin
Total Dioxins (includes, 2,3,7,8 tetra-chlorodibenzo-p-isomer)	1746-01-6	2,3,7,8-Tetrachloro-dibenzo-p-dioxin
Diphenylhydrazine	122-66-7	Hydrazobenzene, 1,2-Diphenylhydrazine, NCI-C01854
Diphenylmethane 4,4-di-isocyanate(MDI)	101-68-8	Benzene 1,1'-Methylenebis (4-Isocyanato- (9CI), Bis(p-Isocyanatophenyl)methane, Caradate 30, Desmodur 44, Hylene M50, Isonate 125M, Isonate 125 MF, Nacconate 300, NCI-C50668
Epichlorohydrin	106-89-8	1-Chloro-2,3-epithio, Chloropropylene sulfide, Thirane, 2-Chloromethyl

SUBSTANCE	CAS REGISTRY #	COMMON SYNONYMS
Epoxypropane (Propylene oxide)	75-56-9	
Ethanethiol	75-08-1	Ethyl hydrosulfide, Ethyl mercaptan, Ethyl thioalcohol, Thioethanol
Ethanolamine	141-43-5	Monoethanolamine, 2-Amino-ethanol, beta Aminoethyl alcohol, Colamine, Glycinol, MEA, Olamine, Thiofaco M-50, USAF EK-1597
Ethyl acetate	141-78-6	Acetic ester, Acetidin, Acetoxyethane, Acetic acid ethyl ester, Vinegar naphtha
Ethyl benzene	100-41-4	EB, NCI-C56393, Phenylethane
Ethyl chloride	75-00-3	Chloroethane, Aethylis chloridum, Anodynon chelen, Ether muriatic, Kelene, Monochloroethane, Narcotile, NCI-C06224
Ethyl ether	60-29-7	Ethane, 1,1'-Oxybis-, anaesthetic ether, Diethyl ether, Diethyl oxide, Ether, Ethoxyethane
Ethylene	74-85-1	Acetene, Bicarburretted hydrogen, Elayl, Ethene, Olefiant gas
Ethylene glycol ethyl ether	110-80-5	2-Ethoxy-ethanol, Cellosolve, Dowanol EE, Glycol monoethyl ether, Hydroxy ether, NCI-C548523, Oxitol, Polysolv EE
Ethylene oxide	75-21-8	Andropolene, Dihydrooxirene, Dimethylene oxide, E.O., Oxiran
Ethyleneimine (Aziridine)	151-56-4	Aminoethylene, Azacyclopropane, Ethylimine
Fluorine	7782-41-4	
Formaldehyde (gas)	50-00-0	BFV, Fannoform, Formol HOCH, Karsan, Methanal, NCI-C02799, Oxomethane, Oxymethylene
Formamide	75-12-7	Carbamaldehyde, Methanamide
Formic acid	64-18-6	Aminic acid, Formylic acid, Hydrogen carboxylic acid, Methanoic acid
Furfural	98-01-1	2-Furaldehyde, Artificial ant oil, Fural, 2-Furyl-methanal, NCI-C56177, Pyromucic aldehyde
Furfuryl alcohol	98-00-0	Furyl alcohol, 2-Furylcarbinol, 2 Hydroxymethylfuran, Methanol, (2-furyl)
Glycidaldehyde	765-34-4	2,3-Epoxypropanal, Epihydrine aldehyde, Clycidal, Oxirane-carboxaldehyde, Propionaldehyde,2,3-epoxy-

SUBSTANCE	CAS REGISTRY #	COMMON SYNONYMS
Hexachlorobutadiene	87-68-3	C-46, Dolen-pur, GP-40-66:120, HCBD, Perchlorobutadiene
Hexachlorocyclopentadiene	77-47-4	1,3-Cyclopentadiene 1,2,3,4,5,5-hexachloro-, C-56, NCI-C55607, Perchlorocyclopentadiene
Hexachloronaphthalene	1335-87-1	
Hexamethylphosphoramide	680-31-9	HMPA, HMPT, HPT, Hexamethylphosphorictriamide
Hydrazine (and acid salts)	302-01-2	
Hydrogen bromide	10035-10-6	Hydrobromic acid, Anhydrous hydrobromic acid,
Hydrogen chloride	7647-01-0	Hydrochloric acid anhydrous,
Hydrogen cyanide	74-90-8	Aero liquid, HCN, Cyclon, Cyclone B, Hydrocyanic acid, Prussic acid, Zacloridiscoids
Hydrogen sulfide	7783-06-4	Stink damp, Sulfureted hydrogen,
Hydroquinone (dihydroxy benzene)	123-31-9	Arcturin, 1,4-Benzenediol, Dihydroxybenzene, Eldoquin, Hydroquinole, p-Hydroxyphenol, USAF EK-356, NCI-C55834, beta-Quinol, Tecquinol, Tenox HQ
2,2-Iminodiethanol	111-42-2	bis(2-Hydroxyethyl)amine, D, DEA, Diethanolamine, Diethylamine, 2,2'-Dihydroxy-diolamine, NCI-C55174
Iodine	7553-56-2	
Isoamyl acetate	123-92-2	Isopentylalcohol acetate, Acetic acid isopentyl ester, Banana, oil, 3-methylbutyl acetate, 3-methylbutyl ethanoate, pearl oil,
Isoamyl alcohol	123-51-3	3-Methyl 1-butanol, Fermentation amyl alcohol, Isobutylcarbinol, Isopentanol, Isopentyl alcohol
Isophorone	78-59-1	Isoacetophorone, Isoforon, NCI-C55618, 1,1,3-Trimethyl-3-Cyclohexene-5-one
Isopropylamine	75-31-0	2-Aminopropane, Monoisopropylamine
Ketene (unsaturated ketone)	463-51-4	Carbomethene, Ethanone, Keto-ethylene
Lead (dust and salts) as Pb	7439-92-1	C.I. Pigment metal 4, C.I. 77575, KS-4, Lead flake, Lead 52, SI, SO
Maleic anhydride	108-31-6	cis-Butenedioic anhydride, 2,5-Fruandione, Maleic acid anhydride, Toxilic anhydride
Manganese	7439-96-5	Colloidial manganese

SUBSTANCE	CAS REGISTRY #	COMMON SYNONYMS
Melamine	108-78-1	Cyanuramide, Cymel, Cyanurotriamide, NCI-C50715
Mercury (metal and salts) as Hg	7439-97-6	NCI-C60399, Quick silver
Methyl cellosolve	109-86-4	Dowanol EM, Ethylene glycol monomethyl ether, Glycomethyl ether, Mecs, Methyl Glycol, Methyl oxitol, Poly-solv EM
Methyl chloride	74-87-3	Chloromethane, Artic, Monochloromethane
Methyl ethyl ketone (MEK)	78-93-3	2-Butanone, Methyl acetone, Meetco
Methyl iodine	74-88-4	Iodomethane, Halon 10001, Methyl iodide
Methyl isocyanate	624-83-9	Isocyanic acid methyl ester, Iso-cyanatomethane
Methyl mercaptan	74-93-1	Methanethiol, Mercaptomethane, Methyl sulfhydrat, Thiomethyl alcohol
Methyl methacrylate	80-62-6	Methacrylic acid methyl ester, Diakon, Methyl 2-methyl-2-propenoate, MME, NCI-C50680, 'Monocite' methacrylate monomer
Methyl-iso-butylketone	108-10-1	2-Pentanone, 4-methyl, Hexone, Isobutyl methyl ketone, Isopropylacetone, MIKl
Methylchloromethylether	107-30-2	CMME, Methyl chloromethyl ether anhydrous,
Methylene Chloride	75-09-2	Dichloromethane, Aerothene MM, Freon 30, Narkotil, Solaesthin, Solmethine,
4,4-Methylene-dianiline	101-77-9	DADPM, DAPM, DDM, Epicure DDM, HT 972, Methylenebis(aniline)
Methylhydrazine	60-34-4	Hydrazomethane, Monomethylhydrazine, MMH
Monochlorobenzene(chlorobenzene)	108-90-7	NCI-C54866, Phenyl chloride
n-phenyl-beta-naphthylamine	135-88-6	Aceto PBN, Agerite powder, Anilinonaphthalene, Neozon D, Neozone, Nonox D, Nilox PBNA, NCI-C02915, Stabilizator AR
Napthalene	91-20-3	Camphor tar, Moth balls, NCI-C52904, White tar
Napthylamine(alpha)	134-32-7	1-Aminonaphthalene, Fast garnet base B, C.I. Azoic diazo component 114
Napthylamine(beta)	91-59-8	2-Aminonaphthalene, Fast scarlet base B, NA, USAF CB-22, 6-Naphthalamine
Nickel (dust and salts) as Ni	7440-02-0	
Nitric acid	7697-37-2	Aqua fortis, Azotic acid, Hydrogen nitrate,
p-Nitroaniline	100-01-6	p-Aminonitrobenzene, Azoamine red zh, Fast red, PNA, Shinnippon fast red GG base, Nitrazol CF extra

SUBSTANCE	CAS REGISTRY #	COMMON SYNONYMS
Nitrobenzene	98-95-3	Essence of mirbane, NCI-C60082, Oil of Mirbane
4-Nitrobiphenyl	92-93-3	p-Phenylnitrobenzene, PNB
Nitrogen mustard	51-75-2	2,2'-Dichloro-N-methyl diethylamine, Caryolysin, Chlormentine, Embichin, HNZ, MBA, N-Methyl-lost, Mutagen, NSC 762
Nitroglycerine	55-63-0	Anginine, Glonoin, Nitrol, Glycerol trinitrate, GTN, NG, NTG, Niglycon, Nitrine, TGC, Nitrolingual, Nitro-span, Perglottal, Nitrolowe, 1,2,3-Propanetriyl nitrate
p-Nitrophenol	100-02-7	4-Hydroxynitrobenzene, NCI-C55992, 4-Nitrophenol
1-Nitropropane	108-03-2	
Nitroso-n-methylurea	684-93-5	Methylnitrosourea, NMH, NMU, NSC 23909
n-Nitrosodimethylamine	62-75-9	DMN, n-Methyl-n-nitrosomethanamine
n-Nitrosomorpholine	59-89-2	4-Nitrosomorpholine, NMOR
p-Nitrosophenol	104-91-6	4-Nitrosophenol, Quinone monoxime, Quinone oxime
m-Nitrotoluene	99-08-1	3-Methylnitrobenzene, 3-Nitrotoluol
p-Nitrotoluene	99-99-0	4-Methylnitrobenzene, NCI-C60537, PNT
Octachloronaphthalene	2234-13-1	Naphthalene octachloro-
Oxalic acid	144-62-7	Ethanedioic acid, NCI-C55209, Ethanedionic acid
Pentachlorophenol (PCP)	87-86-5	Chem-tol, Chlorophen, Cryptogilol, Dowcide 7, Dowcide G, Dowcide EC-7, Durotox, EP 30, Fungifen, Gladz penta, Grundier arbezol, Lauxtol, Liroprem, NCI-C54933, NCI-C55378, NCI-C55655, Penta, Pentasol, Pentacon, Pentakil, Penwar, Permatox, Permacide, Permagard, Permite, Priltox, Santobrite, Santophen, Sinituho, Term-i-trol, Weedone
Phenol	108-95-2	Carbolic acid, Baker's P and S liquid and ointment, Hydroxybenzene, NCI-C50124, Oxybenzene, Phenic acid, Phenyx hydrate, Phenyl hydroxide, Phenylic alcohol

SUBSTANCE	CAS REGISTRY #	COMMON SYNONYMS
p-Phenylenediamine	106-50-3	p-Aminoaniline, 4-Aminoaniline, BASF Ursol D, p-Benzenediamine, 1,4-Benzenediamine, Benzofur D, C.I. 76060, C.I. Developer 13, C.I. Oxidation base 10, Developer PF, Durafur black R, Fouramine D, Fourrine D, Fur black 41867, Fur brown 41866, Furro D, Fur yellow, Futramine D, Nako H, Orsin, Oxidation base 10, Para, Pelagol D, Peltol D, PPD, USAF ED-394, Renal PF, Santoflex IC, Tertral D, Ursol D, Zoba black D
Phenylhydrazine	100-63-0	Hydrazinobenzene
Phosgene	75-44-5	Carbon oxychloride, CG, Chloroformyl chloride, Diphosgene, NCI-C60219
Phosphorus	7723-14-0	White phosphorous, Yellow phosphorus, Bonide blue death rat killer, Rat-Nip
Picric acid	88-89-1	Carbazotic acid, C.I. 10305, 2-Hydroxy-1,3,5-trinitrobenzene, Melinite, Nitroxanthic acid, Phenol trinitrate
Polychlorinated byphenyls (PCBs)	11097-69-1	Arochlor 1242
1,3-Propane sultone	1120-71-4	1,2-Oxathiolane 2,2-dioxide
Propyleneimine	75-55-8	2-Methylaziridine, 2-Methylethylenimine
Pyridine	110-86-1	Azabenzene, Azine, NCI-C55301
Quinoline	91-22-5	1-Azanaphthalene, 1-Benzazine, Benzo(b)pyridine, Chinoleine, Leucol, USAF EK-218, Leuocoline
Quinone	106-51-4	p-benzoquinone, 1,4-Cyclohexadienedione, 1,4-Dioxybenzene, 1,4-Cyclohexadien dioxide, USAF P-220
Resorcinol	108-46-3	m-Dihydroxybenzene, m-Benzenediol, C.I. 76505, C.I. developer 4, Fouramine RS, Fourrine 79, m-Hydroquinone, NCI-C05970, Pelagol RS, Nako TGG, 1,3-Benzenediol, meta-Dihydroxybenzene
Rotenone	83-79-4	Barbasco, Cenol Garden Dust, Green Cross Warble Powder, Tubatoxin
Selenium (dust and salts) as Se	7782-49-2	C.I. 77805
Styrene oxide	96-09-3	Epoxyethylbenzene(8CI), Epoxystyrene, Phenyl oxirane, Phenylethylene oxide, Styrene Epoxide

SUBSTANCE	CAS REGISTRY #	COMMON SYNONYMS
Styrene, monomer	100-42-5	Vinyl benzene, Cinnamene, Cinnamenol, Diarex HF 77, Phenyl Ethylene, NCI-C02200, Stirolo, Styron, Styropor, Cinnamol, Styrolene
Terephthalic acid	100-21-0	p-Benzenedicarboxylic acid
Tetrachlorethylene (perchlorethylene)	127-18-4	Ankilsotin, Carbon dichloride, Carbon bichloride, Deesolv, Dow-per, ENT 1860, Fedal-un, NEMA, NCI-C04580, PERC, Tetralex, Tetraleno, Tetravec, Tetraguer, Tetropil
2,3,7,8-Tetrachlorodibenzofuran	51207-31-9	NCI-C56611
1,1,2,2-Tetrachloroethane	79-34-5	Acetylene tetrachloride, Bonoform, Cellon, Westron
Tetrahydrofuran	109-99-9	1,4-Epoxybutane, Cyclotetramethylene oxide, Diethylene oxide, Firanidine, Hydrofuran, NCI-C60560, Oxacyclopentane, Oxaolane, Tetramethylene oxide, THF
Thallium (dust and salts) as Tl	7440-28-0	Ramor
Titanium oxide	13463-67-7	Bayertitan, Calcotone white T, C.I. 77891, C.I. pigment white 6, Cosmetic white, Hombitan, Horse head, Unitane, 1700 White
Toluene	108-88-3	Methylbenzene, Methacide, Phenylmethane, NCI-C07272
2,4-Toluene-diamine	95-80-7	3-Amino-p-Toluidine, 5-amino-o-Toluidine, Azogen developer H, Benzofur MT, C.I.76025, Developer, Pelagol J, Renal MD, Zoba GKE, Zogen Developer H
2,4-Toluene-di-isocyanate	584-84-9	2,4-Diisocyanato-1-methyl benzene, Isocyanic acid, methylphenylene ester, Helene T, Mondur TDS, Nacconate 100, NCI-C50533, NIAX TDI
o-Toluidine	95-53-4	1-Amino-2-Methylbenzene, o-Methylbenzenamine, o-Tolyamine
1,2,4-Trichlorobenzene	120-82-1	
1,1,1-Trichloroethane (methyl chloroform)	71-55-6	Aerothene TT, Chloroethene, Chloroten, Inhibisol, Methylchloromethane, NCI-C04626, Solvent 111
1,1,2-Trichloroethane	79-00-5	Ethane trichloride, NCI-C04579, beta-T, Vinyl trichloride

SUBSTANCE	CAS REGISTRY #	COMMON SYNONYMS
Trichloroethylene	79-01-6	Acetylene trichloride, Algylen, Anamenth, Benzinol, Blacosolv, Cecolene, Crawhaspol, Dow-tri, Dulceron, Fleck-flip, Germalgene, Lanadin, Narcogen, NCI-C04546, Philex, TCE, Threthylene, trielene, Triklone, Trimar, Tri-plus, Vestrol, Vitran
Turpentine	8006-64-2	
Urethane	51-79-6	
Vinyl Bromide	593-60-2	Bromoethylene
Vinyl chloride	75-01-4	Chloroethylene, Monochloroethylene, Trovidur, VC, VCM, Vinyl C Monomer, Pracarbamine
Vinyl cyclohexene dioxide	106-87-6	7-Oxabicyclo(4.1.0)heptane 3-(epoxyethyl)-, Chissonox 206, EP-206, 1-Epoxyethyl-3,4-epoxycyclohexane, ERLA-2270, ERLA 2271, NCI-C60139, VNOX epoxide 206, Vinyl cyclohexene diepoxide,
Vinyl fluoride	75-02-5	Vinyl fluoride inhibited
Vinylidene chloride (1-1-Dichloroethene)	75-35-4	Sconatex, VDC, 1,1-DCE
Xylene (all isomers)	1330-20-7	Dimethylbenzene, Violet 3, Xylol
Xylidine	1300-73-8	Acid leather brown 2G, Acid orange 24, Aminodimethylbenzene, 11460 brown, Dimethylaniline, Dimethylphenylamine, Resorcine brown J or R,
Zinc (dust and salts) as Zn	7440-66-6	Blue powder, C.I. 77945, C.I. Pigment black 16, C.I. Pigment metal 6, Emany zinc dust, Granular zinc, Jasad, Zinc dust, Zinc Powder

APPENDIX A.4

POTENTIAL HAP'S FOR SOLVENT USAGE OPERATIONS

		Solvent Degreasing	Dry Cleaning	Graphic Arts[1]	Waste Solvent Reclaiming	SC[2]-Flatwood Paneling[3]	SC-Machinery[4]	SC-Appliances[5]	SC-Metal Furniture	SC-Auto/Truck[6]	SC-Fabrics	SC-Cans[7]	SC-Paper, Tapes, Labels	Magnetic Tape Coating	SC-Electrical Insulation	SC-Marine Vessels[8]	Vinyl & Acrylic Coatings[9]	SC-Wood Furniture	SC-Trans. Vehicles[10]	Machine Lubricants	Rubber Tire Manufacturing
Aliphatic Hydrocarbons	Specific Compounds																				
	● Cyclohexane	●												●							
	Generic Compounds																				
	● Naptha's mineral spirits	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●
	● Stoddard solvent			●																	
	● alicyclics		●				●														
Aromatic Hydrocarbons	Specific Compounds																				
	● Benzene	●	●								●									●	
	● Toluene	●		●		●	●	●	●	●		●	●	●		●		●	●		●
	● Xylenes	●	●	●		●	●	●	●	●		●	●	●		●		●	●		●
	● Napthalene[11]																				
	Generic Compounds																				
	● Other aromatics[13]				●	●	●	●	●	●		●	●		●			●	●	●	
Halogenated[12] Hydrocarbons	Specific Compounds																				
	● Chloromethane[11]																				
	● Methylene chloride	●			●																
	● Chloroform[11]																				
	● Carbon tetrachloride	●	●	●																	

		Solvent Degreasing	Dry Cleaning	Graphic Arts[1]	Waste Solvent Reclaiming	SC[2]-Flatwood Paneling[3]	SC-Machinery[4]	SC-Appliances[5]	SC-Metal Furniture	SC-Auto/Truck[6]	SC-Fabrics	SC-Cans[7]	SC-Paper, Tapes, Labels	Magnetic Tape Coating	SC-Electrical Insulation	SC-Marine Vessels[8]	Vinyl & Acrylic Coatings[9]	SC-Wood Furniture	SC-Trans. Vehicles[10]	Machine Lubricants	Rubber Tire Manufacturing
Halogenated[12] Hydrocarbons (concluded)	• 1,1-dichloroethane										•										
	• Trichloroethylene	•	•		•						•										
	• 1,1,1-trichloroethane	•																			
	• Tetrachloroethylene	•	•																		
	• Trichlorotrifluoroethane	•	•		•																
	• Chlorobenzene	•									•										
	• o,p-Dichlorobenzene	•									•										
	Generic Compounds																				
	• Halogenated solvents	•			•																
Alcohols Glycols Ethers Epoxides Phenols	Specific Compounds																				
	• Methanol			•		•				•											•
	• Ethylene glycol			•		•		•		•		•	•						•		
	• Propylene oxide											•									
	• Cresols														•						
	• Phenol			•																	
	Generic Compounds																				
	• alcohols	•		•		•	•	•	•	•		•	•	•				•	•		•
	• glycols								•											•	
	• cellusolves			•		•	•	•		•		•	•	•	•	•		•	•		
	• ethers	•		•			•	•													
	• phenols				•															•	
	• epoxides											•									

		Solvent Degreasing	Dry Cleaning	Graphic Arts[1]	Waste Solvent Reclaiming	SC2-Flatwood Paneling[3]	SC-Machinery[4]	SC-Appliances[5]	SC-Metal Furniture	SC-Auto/Truck[6]	SC-Fabrics	SC-Cans[7]	SC-Paper, Tapes, Labels	Magnetic Tape Coating	SC-Electrical Insulation	SC-Marine Vessels[8]	Vinyl & Acrylic Coatings[9]	SC-Wood Furniture	SC-Trans. Vehicles[10]	Machine Lubricants	Rubber Tire Manufacturing
Ketones Aldehydes	Specific Compounds																				
	• Formaldehyde									●	●										
	• Acetaldehyde[11]																				
	• Furfural																●				
	• Acetone	●		●		●	●		●	●			●			●		●	●		
	• acrolein (propenal)[11]																				
	• Methyl ethyl ketone	●		●		●	●	●	●	●		●	●	●	●	●	●	●	●		
	• Methyl isobutyl ketone			●		●	●		●	●		●	●	●		●		●	●		
	• Cyclohexanone											●									
	Generic Compounds																				
	• Aldehydes											●									
	• Ketones			●		●	●	●	●	●		●	●					●	●		●
Esters Amides	Specific Compounds																				
	• Ethyl acetate			●		●	●		●	●		●	●		●	●		●	●		
	Generic Compounds																				
	• Esters			●		●	●	●	●	●		●	●	●				●	●	●	●
	• Amides											●									
	• Nitrosamines																			●	
Particulates	Specific Compounds																				
	• Cadmium						●	●	●	●						●			●		
	• Chromium						●	●	●	●						●			●		
	• Lead						●	●	●	●						●			●		
	• Zinc						●	●	●	●						●			●		

		Solvent Degreasing	Dry Cleaning	Graphic Arts[1]	Waste Solvent Reclaiming	SC2-Flatwood Paneling[3]	SC-Machinery[4]	SC-Appliances[5]	SC-Metal Furniture	SC-Auto/Truck[6]	SC-Fabrics	SC-Cans[7]	SC-Paper, Tapes, Labels	Magnetic Tape Coating	SC-Electrical Insulation	SC-Marine Vessels[8]	Vinyl & Acrylic Coatings[9]	SC-Wood Furniture	SC-Trans. Vehicles[10]	Machine Lubricants	Rubber Tire Manufacturing
Acids Nitriles	**Specific Compounds**																				
	● Nitrobenzene[11]																				
	Generic Compounds																				
	● Organic acids									●											
	● Nitriles				●																
	● Nitrocompounds											●									
Heterocyclic Compounds	**Specific Compounds**																				
	● Tetrahydrofuran											●		●							
	● Furfural																●				
	Generic Compounds																				
	● Pyrrolidones								●												
Miscellaneous Trade Solvents	So Cal I + II					●															
	Solvesso 100 + 150									●		●									
	Panasolve											●									
	Hi Sol 100											●									
	Tenneco T-125											●									

Footnotes to Table on next page.

FOOTNOTES TO APPENDIX A.4

[1] Category includes organic compounds associated with inks and solvents used in flexography, lithography, offset printing, and textile printing.

[2] SC: surface coating.

[3] Category includes coating of other flat stock.

[4] Category includes coating of miscellaneous metal parts and coating of machinery and equipment.

[5] Category includes all categories of appliances; large and small.

[6] Category includes coating of automobiles and light duty trucks as well as automobile refinishing.

[7] Category includes surface coating of coils, cans, containers, and closures.

[8] Category includes coating of pleasure and commercial marine vessels and maintenance of vessels.

[9] Category includes vinyl, acrylic, and nitrocellulose coatings.

[10] Category includes surface coating of trucks, buses, railroad cars, and other transportation vehicles.

[11] From list of compounds emitted from solvent use presented in Ref. 14. No information on specific s categories using these compounds was located.

[12] Appendix A.3 provides a list of stabilizers that may be used in halogenated hydrocarbons.

[13] Category includes polycyclic organic matter.

APPENDIX A.5

ADDITIONAL INFORMATION FOR THE SOCMI SOURCE CATEGORY

TABLE A.5-1. REFERENCES FOR ADDITIONAL INFORMATION ON SOCMI[a]

1. U.S. EPA. *Standard Support and Environmental Impact Statement: Emission Standard for Vinyl Chloride*. EPA-450/2-75-009a. October 1975.

2. U.S. EPA. *Standard Support and Environmental Impact Statement: Volume 2 Promulgated Emission Standard for Vinyl Chloride*. EPA-450/2-75-009b. September 1976.

3. U.S. EPA. *Source Assessment: Phthalic Anhydride (Air Emissions)*. EPA-600/2-76-032d. December 1976.

4. U.S. EPA. *Source Assessment: Acrylonitrile Manufacture (Air Emissions)*. EPA-600/2-77-107j. September 1977.

5. U.S. EPA. *Source Assessment: Urea Manufacture*. EPA-600/2-77/107l. November 1977.

6. U.S. EPA. *Source Assessment: Polychloroprene State of the Art*. EPA-600-2-77-107o. December 1977.

7. U.S. EPA. *Industrial Process Profiles for Environmental Use: Chapter 6. The Industrial Organic Chemical Industry*. EPA-600/2-77-023f. February 1977.

8. U.S. EPA. *Industrial Process Profiles for Environmental Use: Chapter 7. Organic Dyes and Pigments Industry*. EPA-600/2-77-023g. February 1977.

9. U.S. EPA. *Source Assessment: Polyvinyl Chloride*. EPA-600/2-78-004i. May 1978.

10. U.S. EPA. *Source Assessment: Acrylic Acid Manufacture: State of the Art*. EPA-600/2-78-004w. August 1978.

11. U.S. EPA. *Source Assessment: Noncriteria Pollutant Emissions (1978 Update)*. EPA-600/2-78-004t. July 1978.

12. U.S. EPA. *Source Assessment: Chlorinated Hydrocarbon Manufacture*. EPA-600/2-79-019g. August 1979.

13. U.S. EPA. *Status Assessment of Toxic Chemicals: Acrylonitrile*. EPA-600/2-79-210a. December 1979.

14. U.S. EPA. *Status Assessment of Toxic Chemicals: Benzene*. EPA-600/2-79-210d. December 1979.

(Continued)

TABLE A.5-1 (Continued)

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17. U.S. EPA. Status Assessment of Toxic Chemicals: Polybrominated Biphenyls. EPA-600/2-79-210k. December 1979.

18. U.S. EPA. Status Assessment of Toxic Chemicals: Polynuclear Aromatic Hydrocarbons. EPA-600/2-79-210l. December 1979.

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21. U.S. EPA. Status Assessment of Toxic Chemicals: Vinylidene Chloride. EPA-600/2-79-210o. December 1979.

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24. U.S. EPA. Benzene Emissions from the Ethylbenzene/Styrene Industry - Background Information for Proposed Standards. EPA-450/3-79-035a. August 1980.

25. U.S. EPA. Benzene Emissions from Benzene Storage Tanks - Background Information for Proposed Standards. EPA-450/3-80-034a. December 1980.

26. U.S. EPA. Benzene Fugitive Emissions - Background Information for Proposed Standards. EPA-450/3-80-032a. November 1980.

27. U.S. EPA. VOC Fugitive Emissions in Synthetic Organic Chemicals Manufacturing Industry - Background Information for Proposed Standards. EPA-450/3-80-033a. November 1980.

28. U.S. EPA. Fugitive Emission Sources of Organic Compounds - Additional Information on Emissions, Emission Reductions, and Costs. EPA-450/3-82-010. April 1982.

(Continued)

TABLE A.5-1 (Continued)

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30. U.S. EPA. Vinyl Chloride: A Review of National Emission Standards. EPA-450/3-82-003. February 1982.

31. U.S. EPA. Air Oxidation Processes in Synthetic Organic Chemical Manufacturing Industry - Background Information for Proposed Standards. EPA-450/3-82-001a. October 1983.

32. U.S. EPA. Health Assessment Document for 1,1,2-Trichloro-1,2,2-Trifluoroethane (Chlorofluorocarbon CFC-113). EPA-600/8-82-002. September 1983.

33. U.S. EPA. Benzene Emissions from Benzene Storage Tanks: Background Information for Proposal to Withdraw Proposed Standards. EPA-450/3-84-004. March 1984.

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35. U.S. EPA. Benzene Emissions from Ethylbenzene/Styrene Plants - Background Information for Proposal to Withdraw Proposed Standards. EPA-450/3-84-003. March 1984.

36. U.S. EPA. Locating and Estimating Air Emissions from Sources of Chloroform. EPA-450/4-84-007c. March 1984.

37. U.S. EPA. Locating and Estimating Air Emissions from Sources of Carbon Tetrachloride. EPA-450/4-84-007b. March 1984.

38. U.S. EPA. Locating and Estimating Air Emissions from Sources of Formaldehyde. EPA-450/4-84-007e. March 1984.

39. U.S. EPA. Benzene Fugitive Emission - Background Information for Promulgated Standards. EPA-450/3-80-032b. June 1982.

40. U.S. EPA. Distillation Operations in Synthetic Organic Chemical Manufacturing - Background Information for Proposed Standards. EPA-450/3-83-005a. December 1983.

41. U.S. EPA. Locating and Estimating Air Emissions from Sources of Ethylene Dichloride. EPA-450/4-84-007d. March 1984.

(Continued)

TABLE A.5-1 (Continued)

42. U.S. EPA. Locating and Estimating Air Emissions from Sources of Acrylonitrile. EPA-450/4-84-007a. March 1984.

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[a] Source: Reference 1.

TABLE A.5-2. SOCMI REACTOR PROCESSES[a]

Reactor Processes
Oxidation
Halogenation
Hydrogenation
Esterification
Alkylation
Sulfonation
Dehydrogenation
Hydrolysis
Reforming
Carbonylation
Oxyacetylation
Nitration
Dehydration
Ammonolysis
Condensation
Dealkylation

[a] Source: Reference 2.

TABLE A.5-3. HIGH VOLUME CHEMICALS PRODUCED BY AIR OXIDATION[a]

1. Acetaldehyde
2. Acetic Acid
3. Acetone
4. Acetonitrile
5. Acetophenone
6. Acrolein
7. Acrylic Acid
8. Acrylonitrile
9. Anthraquinone
10. Benzaldehyde
11. Benzoic Acid
12. 1,3-Butadiene
13. p-t-Butyl Benzoic Acid
14. n-Butyric Acid
15. Crotonic Acid
16. Cumene Hydroperoxide
17. Cyclohexanol
18. Cyclohexanone
19. Ethylene Dichloride
20. Dimethyl Terephthalate
21. Ethylene Oxide
22. Formaldehyde
23. Formic Acid
24. Glyoxal
25. Hydrogen Cyanide
26. Isobutyric Acid
27. Isophthalic Acid
28. Maleic Anhydride
29. Methyl Ethyl Ketone
30. α-Methyl Styrene
31. Phenol
32. Phthalic Anhydride
33. Propionic Acid
34. Propylene Oxide
    (tert butyl hydroperoxide)
35. Styrene
36. Terephthalic Acid

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[a] Source: Reference 3.

TABLE A.5-4. HIGH VOLUME SOCMI CHEMICALS PRODUCED BY REACTOR PROCESSES OTHER THAN AIR OXIDATION[a]

Unit Process I.D.[b]	Chemical	Unit Process I.D.[b]	Chemical
ALK-1	Linear Alkylbenzene	CLE-1	Phenol/Acetone
ALK-2	Linear Alkylbenzene		
ALK-3	Ethylbenzene	CON-1	Acetic Anhydride
ALK-4	Tetra Ethyl - Tetra Methyl Lead	CON-2	Acetic Anhydride
		CON-3	Nonylphenol, Exthoxylated
ALK-5	Ethylbenzene	CON-4	Bisphenol - A
ALK-6	Linear Alkylbenzene		
ALK-7	Linear Alkylbenzene	CRE-1	Benzene
ALK-8	Cumene		
ALK-9	Cumene	DEH-1	Acetone
ALK-10	Cumene	DEH-2	Methyl Ethyl Ketone
ALK-11	Cumene	DEH-3	Styrene
ALK-12	Cumene	DEH-4	Styrene
ALK-13	Dimethyldichlorosilane	DEH-5	n-Paraffins
ALK-14	Nonylphenol	DEH-6	Acetone
		DEH-7	Acetone
AMMI-1	Caprolactam	DEH-8	Acetone
		DEH-9	Methyl Ethyl Ketone
AMM-1	Ethanolamines	DEH-10	Methyl Ethyl Ketone
AMM-2	Ethanolamines	DEH-11	Methyl Ethyl Ketone
		DEH-12	Cyclohexanone
CAR-1	Acetic Acid		
CAR-2	Methanol	DEHC-1	Vinylidene Chloride
CAR-3	Methanol	DEHC-2	Vinylidene Chloride
CAR-4	Methanol	DEHC-3	Vinylidene Chloride
CHL-1	Ethylene Dichloride	DEHY-1	Urea
CHL-2	Chlorobenzene		
CHL-4	Chlorobenzene	EST-1	Ethyl Acrylate
CHL-5	Ethylene Dichloride	EST-2	Methyl Methacrylate
CHL-6	Ethylene Dichloride	EST-3	Ethyl Acetate
CHL-7	Ethylene Dichloride	EST-4	Dioctyl Phatalate
CHL-8	Methylene Chloride	EST-5	Dimethyl Terephthalate
CHL-9	Ethylene Dichloride	EST-6	Ethyl Acetate
CHL-10	Ethylene Dichloride	EST-7	Butyl Acetate
CHL-11	Methylene Chloride	EST-8	Ethylene Glycol Monoethylether Acetate
CHL-12	1,4-Dichlorobutene		
CHL-13	Methylchloroform		
CHL-14	Allyl Chloride	ETH-1	MTBE
CHL-15	Mono-Chloroacetic Acid		

(Continued)

TABLE A.5-4. HIGH VOLUME SOCMI CHEMICALS PRODUCED BY REACTOR PROCESSES OTHER THAN AIR OXIDATION[a] (Continued)

Unit Process I.D.[b]	Chemical
ETHY-1	Butynediol
FLU-1	Freon - 12
FLU-2	Freon - 113
FLU-3	Freon - 11,12,113,114,22
HYD-1	Hexamethylene Diamine
HYD-2	Hexamethylene Diamine
HYD-3	Cyclohexane
HYD-5	Aniline
HYD-6	Butanediol
HYD-7	Cyclohexanol
HYD-8	Toluene Diamine
HYD-9	n-Butyl Alcohol
HYD-10	Hexamethylene Diamine
HYD-11	β-Butylene
HYDC-3	Methyl Chloride
HYDC-4	Methyl Chloride
HYDC-5	Methyl Chloride
HYDC-6	Ethyl Chloride
HYDC-7	Ethyl Chloride
HYDC-8	Ethyl Chloride
HYDC-9	Ethyl Chloride
HYDC-10	Ethyl Chloride
HYDC-11	Ethyl Chloride
HYDC-12	Epichlorohydrin
HYDF-1	Oxo Alcohols
HYDF-2	Butyraldehyde
HYDI-1	Adiponitrile
HYDO-1	Propylene Oxide
HYDO-2	Sec-Butyl Alcohol
HYDO-3	Glycerin
HYDR-1	Propylene Glycol
HYDR-2	Ethylene Glycol
HYDR-3	Ethylene Glycol
HYDR-4	Ethylene Glycol
NIT-1	Nitrobenzene
NIT-2	Dinitrotoluene
NIT-3	Dinitrotoluene
NUT-1	Linear Alkylbenzene
NUT-2	Linear Alkylbenzene
NUT-3	Dodecylbenzene Sulfonic Acid, Sodium Salt
OLIG-1	Octene
OLIG-2	Dodecene
OLIG-3	α-Butylene
OLIG-4	Tripropylene
OLIG-5	Dodecene
OXI-1	Adipic Acid
OXI-2	Adipic Acid
OXI-3	Adipic Acid
OXI-4	Ethylene Oxide
OXYA-1	Vinyl Acetate
OXYC-1	Ethylene Dichloride
PHO-1	Toluene Diisocyanate
PYR-1	Ketene
PYR-2	Ethylene
PYR-3	Ketene
PYR-4	Propylene
PYR-5	Ethylene
PYR-6	Vinyl Chloride Monomer
PYR-7	Bivinyl
SUL-1	Dodecylbenzene Sulfonic Acid
SULP-1	Carbon Disulfide

(Continued)

TABLE A.5-4. HIGH VOLUME SOCMI CHEMICALS PRODUCED BY REACTOR PROCESSES OTHER THAN AIR OXIDATION[a] (Concluded)

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[a] Source: Reference 2.

[b] Process units are identified by the chemical reaction associated with their manufacture. Reaction codes are as follows:

ALK - Alkylation
AMMI - Ammination
AMM - Ammonolysis
CAR - Carbonylation
CHL - Chlorination
CLE - Cleavage
CON - Condensation
CRE - Catalytic Reforming
DEHY - Dehydration
DEH - Dehydrogenation
DEHC - Dehydrochlorination
EST - Esterification
ETH - Etherification
ETHY - Ethynylation
FLU - Fluorination

HYD - Hydrogenation
HYDC - Hydrochlorination
HYDF - Hydroformylation
HYDI - Hydrodimerization
HYDO - Hydrolysis
NIT - Nitration
NUT - Neutralization
OLIG - Oligomerization
OXI - Oxidation (Pure O_2)
OXYA - Oxyacetylation
OXYC - Oxychlorination (Pure O_2)
PHO - Phosgenation
PYR - Pyrolysis
SUL - Sulfonation
SULP - Sulfurization (Vapor Phase)

EXAMPLE

ETHYLBENZENE/STYRENE PRODUCTION[a]

As an example of the type of emissions associated with the SOCMI, we will look at the emissions from the production of styrene from benzene and ethylene by alkylation and dehydrogenation reactions where ethylbenzene is produced as an intermediate. A process flow diagram for styrene production is shown in Figure A.5-1; potential emission sources are also indicated on the diagram. The types of emission sources are:

a) storage and handling emissions

b) reactor process emissions
  - alkylation reactor vents

c) separation process emissions
  - column vents (benzene drying column, ethylbenzene purification column, styrene purification column, hydrogen separation vent)

d) fugitive emissions
  - groups of valves, pump seals, etc.

The HAP's which may potentially be present in these emission streams include:

Organic Compounds (Vapor)	Inorganic Compounds (Vapor)
Benzene	Hydrogen Chloride
Ethylbenzene	
Polyethylbenzene	
Ethylene	
Styrene	
Toluene	
Methane	
Ethane	
Aliphatic hydrocarbons	
Aromatic hydrocarbons	

Table A.5-5 gives estimates of uncontrolled benzene and total VOC emissions for a plant with a styrene production capacity of 6.6×10^8 lb/yr.

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[a] See Reference 4.

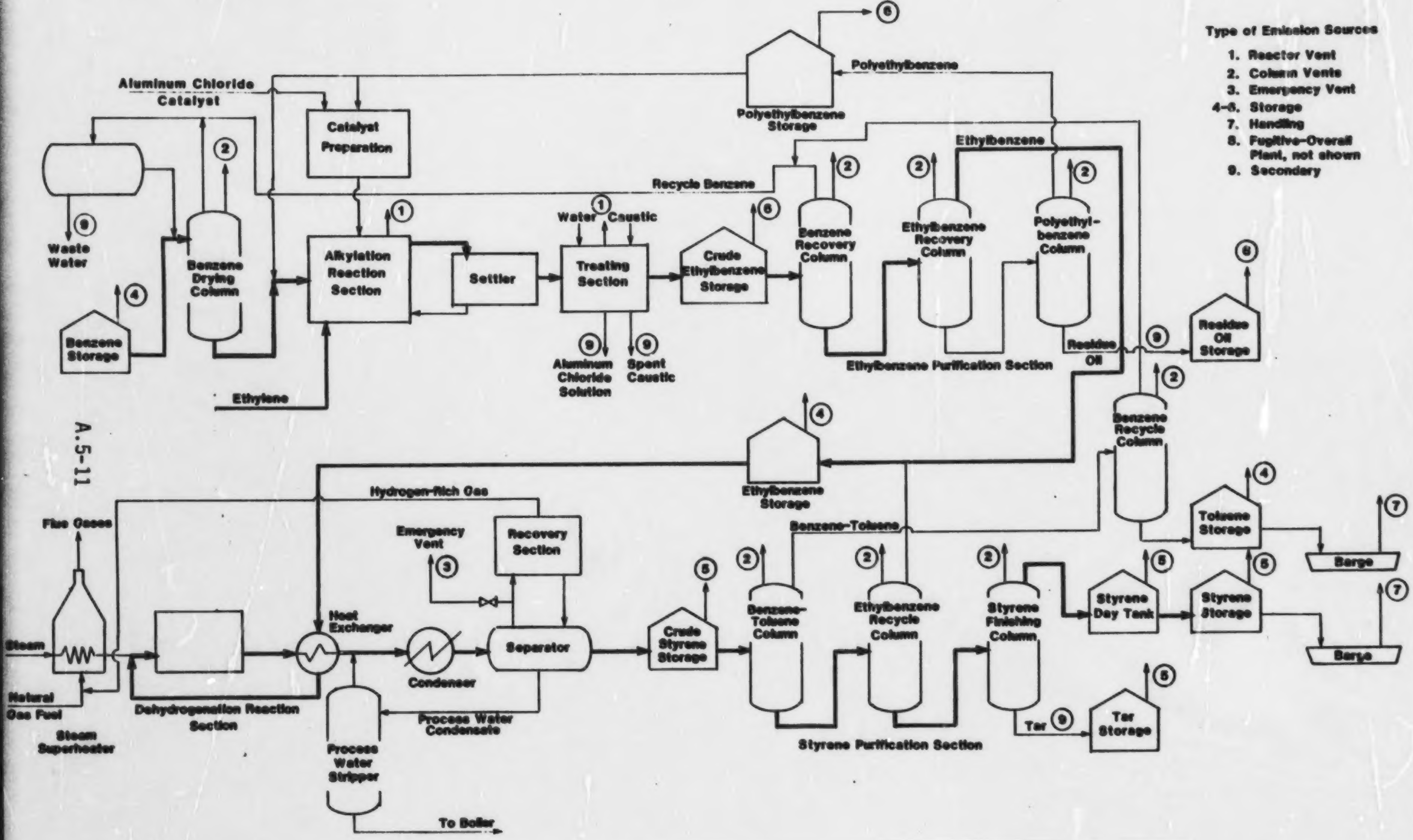
Type of Emission Sources
1. Reactor Vent
2. Column Vents
3. Emergency Vent
4–6. Storage
7. Handling
8. Fugitive–Overall Plant, not shown
9. Secondary
Aluminum Chloride Catalyst
Waste Water
Benzene Storage
Benzene Drying Column
Catalyst Preparation
Alkylation Reaction Section
Ethylene
Settler
Water
Caustic
Treating Section
Aluminum Chloride Solution
Spent Caustic
Crude Ethylbenzene Storage
Recycle Benzene
Polyethylbenzene Storage
Polyethylbenzene
Benzene Recovery Column
Ethylbenzene Recovery Column
Polyethylbenzene Column
Ethylbenzene
Ethylbenzene Purification Section
Residue Oil
Residue Oil Storage
Ethylbenzene Storage
Benzene Recycle Column
Hydrogen-Rich Gas
Flue Gases
Steam
Natural Gas Fuel
Steam Superheater
Dehydrogenation Reaction Section
Heat Exchanger
Condenser
Emergency Vent
Recovery Section
Separator
Process Water Condensate
Process Water Stripper
To Boiler
Crude Styrene Storage
Benzene-Toluene
Benzene-Toluene Column
Ethylbenzene Recycle Column
Styrene Finishing Column
Tar
Styrene Purification Section
Styrene Day Tank
Tar Storage
Toluene Storage
Styrene Storage
Barge
Barge

Figure A.5-1. Process flow diagram for production of styrene from benzene and ethylene by dehydrogenation of ethylbenzene.

TABLE A.5-5. ESTIMATES OF UNCONTROLLED EMISSIONS FROM AN ETHYLBENZENE/STYRENE MANUFACTURING PLANT[a]

Emission Source	Emissions Ratio (10^3 lb/lb)[b]		Emissions Rate (lb/hr)	
	Benzene	Total VOC	Benzene	Total VOC
Alkylation reaction vent	0.64	1.94	22	66
Column vents	3.74	5.74	128	199
Storage and handling	1.25	1.47	44	51
Fugitive emissions	0.24	1.12	8.4	37
Secondary emissions[c]	0.15	0.19	5.1	6.6
TOTAL	6.0	10.5	208	360

[a] Source: Reference 4.

[b] lb of emission per lb of product.

[c] These emissions are associated with waste liquid streams generated in the process.

References

1. U.S. EPA. Air Toxics Information Clearinghouse: Bibliography of Selected EPA Reports and Federal Register Notices. EPA Contract No. 68-02-3889. January 1985.

2. U.S. EPA. Reactor Processes in Synthetic Organic Chemical Manufacturing - Background Information for Proposed Standards. Draft EIS. October 1984.

3. U.S. EPA. Air Oxidation Processes in Synthetic Organic Chemical Manufacturing Industry Background Information for Proposed Standards. EPA-450/3-82-001a. October 1983.

4. U.S. EPA. Organic Chemical Manufacturing Volume 6: Selected Processes. EPA-450/3-80-028a. December 1980.

APPENDIX A.6

ADDITIONAL INFORMATION ON PETROLEUM RELATED INDUSTRIES

Oil and Gas Production Industry

- I. Exploration and Site Preparation
  - 1. Exploration
  - 2. Site Preparation
- II. Well Drilling and Completion
  - 1. Drilling
  - 2. Mud Circulaton
  - 3. Format Evaluation
  - 4. Well Completion
- III. Crude Processing
  - 1. Water Removal
  - 2. Gas-Oil Separation
  - 3. Crude Storage
- IV. Natural Gas Processing
  - 1. Liquid Hydrocarbon Recovery
  - 2. Acid Gas Removal
  - 3. Sulfur Recovery
  - 4. Dehydration
  - 5. Product Separation
  - 6. LPG Storage
  - 7. Gasoline Storage
- V. Secondary and Tertiary Recovery Techniques
  - 1. Displacement
  - 2. Fracturing
  - 3. Acid Treatment
  - 4. Thermal Treatment

Petroleum Refining Industry

I. Crude Separation
   1. Crude Storage
   2. Desalting
   3. Atmospheric Distillation
   4. H_2S Removal
   5. Sulfur Recovery
   6. Gas Processing
   7. Vacuum Distillation
   8. Hydrogen Production

II. Light Hydrocarbon Processing
   1. Naphtha Hydrodesulfurization
   2. Catalytic Reforming
   3. Isomerization
   4. Alkylation
   5. Polymerization
   6. Light Hydrocarbon Storage and Blending

III. Middle and Heavy Distillate Processing
   1. Chemical Sweetening
   2. Hydrodesulfurization
   3. Fluid Bed Catalytic Cracker
   4. Moving Bed Catalytic Cracker
   5. Hydrocracking
   6. Lube Oil Processing
   7. Lube and Wax Hydrotreating
   8. Middle and Heavy Storage and Blending

IV. Residual Hydrocarbon Processing
   1. Deasphalting
   2. Asphalt Blowing
   3. Residual Oil Hydrodesulfurization
   4. Visbreaking
   5. Coking
   6. Residual Hydrocarbon Storage and Blending

Petroleum Refining Industry (cont'd.)

V. Auxillary Processes
   1. Wastewater Treating
   2. Steam Production
   3. Process Heaters
   4. Pressure Relief and Flare Systems

Basic Petrochemicals Industry

I. Olefins Production Processes
   1. Thermal Cracking
   2. Oil Quenching
   3. Water Quenching
   4. Compression
   5. Acid Gas Removal
   6. Water Removal
   7. Demethanation
   8. C_2 Separation
   9. C_3 Separation
   10. C_4 Separation
   11. Heavy Fractionation

II. Butadiene Production Processes
   1. Separation and Purification
   2. Butane Dehydrogenation
   3. Butenes Dehydrogenation

III. BTX Production Processes
   1. Hydrotreating
   2. Aromatics Extraction
   3. C_6 - C_9 + Aromatics Separation
   4. C_8 Aromatics Fractionation
   5. Para-xylene Crystallization
   6. Para-xylene Adsorption

Basic Petrochemicals Industry (cont'd.)

- III. BTX Production Processes (cont'd.)
  - 7. C_8 Aromatics Isomerization
  - 8. Toluene Disproportionation/ Transalkylation
  - 9. Hydrodealkylation
- IV. Naphthalene Production Processes
  - 1. Extraction of Dicyclic Aromatics
  - 2. Hydrodealkylation to Produce Naphthalene
- V. Cresols and Cresylic Acids Production Processes
  - 1. Acidification
  - 2. Product Recovery
- VI. Normal Paraffin Production Processes
  - 1. Separation of Normal Paraffins

APPENDIX A.7

ADDITIONAL INFORMATION ON CONTROLS FOR PROCESS FUGITIVE EMISSIONS

(Table A.7-1[a] Miscellaneous Specific Operation Standards)

	Ventilation		
Operation or Industry	Type of Hood	Air Flow or Capture Velocity	Minimum Design Duct Velocity fpm
Abrasive Wheel Manufacture			
Grading screen	Enclosure--booth	50 fpm at face	3000
Barrels	Close canopy	400 fpm at face	3000
Grinding wheel dressing	Enclosure--booth	400 fpm at face	3000
Aluminum Furnaces	Enclosure	150-200 fpm through opening	2000
Asbestos			
Bagging	Enclosure booth	250 fpm through all openings	3500
Carding	Enclosure	1600 cfm/card	3500
Crushing	Enclosure	150 fpm through all openings	3500
Drilling of panels containing asbestos	Moveable hood	400 fpm capture velocity	4500
Dumping	Booth	250 fpm face velocity	3500
Grinding of brake shoes	Enclosure	400 fpm - minimum capture at the tool rest	3500
Hot press for brake shoes	Enclosure	250 fpm through all openings	3500
Mixing	Booth	250 fpm face velocity	3500
Preform press	Enclosure	250 fpm through all openings	3500
Screening	Enclosure	200 fpm through all openings but not less than 25 cfm/sq ft screen areas	3000
Spool winding	Local Hoods	50 cfm/spool	3500
Spinning and twisting	Partial	50 cfm/ spool	3500
Weaving	Canopy with baffles	50 fpm through openings	3500
Auto Parking Garage	2 Level	500 cfm/Parking Space	
Ceramic			
Dry pan	Enclosure	200 fpm through all openings	3500
Dry press	Local at die	500 cfm	3500
	At supply bin	500 cfm	3500
Aerographing	Booth	100 fpm (face)	----
Spraying (lead glaze)	Booth	400 fpm (face)	2000

TABLE A.7-1[a] MISCELLANEOUS SPECIFIC OPERATION STANDARDS (concluded)

Operation or Industry	Type of Hood	Ventilation Air Flow or Capture Velocity	Minimum Design Duct Velocity fpm
Coating pans (pharmaceutical)	Air flow into opening of pan	100-150 fpm through opening	3000
Cooling tunnels (foundry)	Enclosure	75-100 cfm per running foot of enclosure	----
Core knockout (Manual)	Large side-draft or semi-booth--exhaust near floor	200-250 cfm/sq ft dust producing working area	3500
Core sanding (on lathe)	Downdraft under work	100 fpm at source	3500
Forge (hand)	Booth	200 fpm at face	1500
Outboard Motor Test Tank	Side draft	200 cfm/sq ft of tank opening	
Packaging Machines	Booth Downdraft Complete Enclosure	50-100 fpm at face 95-150 fpm down 100-400 fpm opening	3000 to 4000
Paper Machine	Canopy	200-300 fpm at face	1500
Quartz fusing	Booth on bench	150-200 fpm at face	----
Rotary Blasting Table	Enclosure	500 fpm through all openings when in operation	3500
Silver Soldering	Free Hanging	100 fpm at source	2000
Steam Kettles	Canopy	150 fpm at face	2000
Varnish Kettles	Canopy	200-250 fpm at face	1500
Wire Impregnating	Covered tanks	200 cfm/sq ft of opening	----

[a] Source: Reference 1.

Reference

1. Committee on Industrial Ventilation. Industrial Ventilation: A Manual of Recommended Practices. 17th Edition. Lansing, MI. 1982.

APPENDIX A.8*

CONTROL TECHNIQUES FOR INDUSTRIAL PROCESS FUGITIVE PARTICULATE EMISSIONS (IPFPE)

Appendix A.8 contains industry-specific control techniques for fugitive particulate emission sources. The industries presented are as follows:

Industry	Page
Mining (Generic)	A.8-2
Primary Aluminum Production	A.8-3
Primary Copper Smelting	A.8-4
Iron Production	A.8-5
Steel Manufacturing	A.8-6
Primary Lead Smelting	A.8-7 & 8
Primary Zinc Production	A.8-9
Secondary Aluminum Smelters	A.8-10
Secondary Copper & Brass/Bronze Smelters	A.8-11
Foundry Operations (Generic)	A.8-12
Secondary Lead Smelting	A.8-13 & 14
Secondary Zinc Production	A.8-15 & 16
Lime Manufacturing	A.8-17
Portland Cement Manufacturing	A.8-18 & 19
Concrete Batching	A.8-20
Asphaltic Concrete Manufacturing	A.8-21

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*U.S. EPA. Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions. EPA-450/3-77-010. March 1977.

CONTROL TECHNIQUES FOR MINING IPFPE SOURCES

	Control	
Source	Applicate control method/comments	Estimated efficiency
Overburden removal	Watering/Rarely practiced	50%
Drilling/Blasting	Watering, cyclones, or fabric filters for drilling/Employment of control equipment increasing Mats for blasting/Very rarely employed	no data
Shovels/Truck ore loading	Watering/Rarely practiced.	50%
Haul road truck transport	Watering/By far the most widely practiced of all mining fugitive dust control methods	50%
	Surface treatment with penetration chemicals/Employment of this method increasing	50%
	Paving/Limited practice	90-95%
Truck dumping	Watering/Rarely practiced	50%
	Ventilated enclosure to control device/Rarely employed	85-90%
Crushing	Adding water or dust suppressants to material to be crushed and venting to baghouse/Fairly commonly practiced	95%
Transfer/Conveying	Enclosed conveyors/Commonly employed	90-99%
	Enclosure and exhausting of transfer points to fabric filter/Limited employment	85-99% (depends on control devices)
Cleaning	Very little control needed since basically a wet process	
Storage	Continuous spray of chemical on material going to storage piles/Rarely practiced	90%
	Watering (sprinklers or trucks)/Rarely practiced	50%
Waste disposal/Tailing piles	Chemical stabilization/Limited practice	80%
	Vegetation/Commonly practiced	65%
	Combined chemical-vegetative stabilization/Rarely employed	90%
	Slag cover/Limited practice	90-99%

CONTROL TECHNIQUES FOR PRIMARY

ALUMINUM PRODUCTION IPFPE SOURCES

Industry: Primary Aluminum Production	Negligible emissions	IPFPE source typically uncontrolled	FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
			Control technologies identified in Section 3.3.2	Preventative procedures and operating changes							Capture methods				Removal equipment		
				Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system		Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	ESP
1. Materials receving and handling (including conveying, grinding, screening, mixing, and paste preparation)			✓												x		
2. Anode baking									x		x					x	x
3. Electrolytic reduction cell							x	x	x		x		●		◆	x	x
4. Refining and casting							x		x		x				x	x	

x Typical control technique.

● In use (but not typical) control technique.

◆ Technically feasible control technique.

CONTROL TECHNIQUES FOR

PRIMARY COPPER SMELTING IPFPE SOURCES

Industry: Primary Copper Smelting	Negligible emissions	IPFPE source typically uncontrolled	FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
			Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system		Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	ESP
1. Unloading and handling of ore concentrates			✓														
2. Ore concentrate storage			✓														
3. Limestone and flux unloading and handling			✓														
4. Limestone flux storage			✓														
5. Roaster charging											+		+		o		o
6. Roaster leakage								o	o				+		o		o
7. Calcine transfer					o						o	o	+		o		o
8. Charging reverberatory furnace		✓									o	o	+		o		o
9. Tapping of reverberatory		✓									o	o	+		o		o
10. Reverberatory furnace leakage		✓						+			o	o	+		o		o
11. Slag tapping		✓									o	o	+		o		o
12. Converter charging		✓					o				+	+	+		+		
13. Converter leakage									x		+	+	+		+		
14. Slag tapping from converter		✓					o				+	+	+		+	+	+
15. Blister copper tapping		✓					o				+	+	+		+		
16. Blister copper transfer		✓									+	+	+		+		
17. Charging blister copper to fire refining furnace		✓										+	+		+		
18. Copper tapping and casting		✓										+	+		+		
19. Slag tapping and handling		✓										+	+		+		
20. Slag pile dumping and cooling		✓									+	+			+	+	

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

CONTROL TECHNIQUES FOR IRON PRODUCTION IPFPE SOURCES

Industry: Iron Production	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS													
				Preventative procedures and operating changes							Capture methods				Removal equipment		
				Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system	Minimize free-fall distance (chute or other device)	Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	Wet wall
1. Ship or railroad car unloading			✓														
2. Iron ore storage			✓														
3. Iron ore handling and transfer			✓														
4. Limestone storage			✓														
5. Limestone handling and transfer			✓														
6. Coke storage			✓														
7. Coke handling and transfer			✓														
8. Blast furnace flue dust storage	✓																
9. Blast furnace flue dust handling and transfer			✓														
10. Sinter machine windbox discharge	✓			o	x					+	+				+		
11. Sinter machine discharge and screens				x	x			o	o		x				x		
12. Sinter cooler					+						x				x		
13. Sinter storage			✓														
14. Sinter handling and transfer			✓														
15. Blast furnace charging	✓																
16. Blast furnace upsets (slips)						o	o	+									+
17. Blast furnace tapping - iron											+	+			+		
18. Blast furnace tapping - slag											+	+			+		
19. Slag handling				+	+					+	+				+		
20. Slag dumping and storage				+						+							
21. Slag crushing				x							x		+		x		

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

CONTROL TECHNIQUES FOR
STEEL MANUFACTURING IPFPE SOURCES

Industry: Steel Manufacturing	Negligible emissions	IPFPE source typically uncontrolled	FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
			Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system		Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation	Enclosure of furnace area with evacuation	Fabric filter	Scrubber	ESP
1. Scrap steel unloading, transfer and storage	✓																
2. Flux material unloading, transfer, and storage	✓																
3. Molten pig iron transfer from torpedos to charge ladles (hot metal reladling)											o	o			o		
4. Basic oxygen furnace - roof monitor (total)													+	o	o		
4a. Charging											o	o	+		o		
4b. Leakage	✓																
4c. Tapping-steel											o	o	+	o	o		
4d. Tapping-slag											o	o	+	o	o		
5. Open hearth furnace - roof monitor (total)													+		o		
5a. Charging											o	o			o		
5b. Leakage								o					o		o		
5c. Tapping-steel											o	o			o		
5d. Tapping-slag											o	o			o		
6. Electric arc furnace - roof monitor (total)													o	o	o		
6a. Charging											o	o	o	o	o		
6b. Leakage								o					o	o	o		
6c. Tapping-steel											o	o	o	o	o		
6d. Tapping-slag											o	o	o	o	o		
7. Ingot casting							o				o	o	+		o		
8. Molten steel reladling												o				o	
9. Scarfing											o		o		o		o

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

CONTROL TECHNIQUES FOR
PRIMARY LEAD SMELTING IPFPE SOURCES

Industry: Primary Lead Smelting	Negligible emissions	IPFPE source typically uncontrolled	FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
			Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system		Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	ESP
1. Railroad car and truck unloading																	
1a. Limestone			✓														
1b. Silica sand			✓														
1c. Lead ore concentrate			✓														
1d. Iron ore			✓														
1e. Coke			✓														
2. Blast furnace flue dust																	
2a. Storage	✓																
2b. Handling and transfer	✓																
3. Limestone																	
3a. Storage		✓	✓														
3b. Handling and transfer		✓	✓														
4. Silica sand																	
4a. Storage		✓	✓														
4b. Handling and transfer		✓	✓														
5. Lead ore concentrate																	
5a. Storage		✓	✓														
5b. Handling and transfer		✓	✓														
6. Iron ore																	
6a. Storage		✓	✓														
6b. Handling and transfer		✓	✓														
7. Coke																	
7a. Storage		✓	✓														
7b. Handling and transfer		✓	✓														

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

CONTROL TECHNIQUES FOR
PRIMARY LEAD SMELTING IPFPE SOURCES
(concluded)

Industry: Primary Lead Smelting			Fugitive emissions capture and control methods														
				Preventive procedures and operating changes							Capture methods				Removal equipment		
	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Decrease exhaust rate of primary control system		Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	ESP
8. Mixing and pelletizing					●								●		●		
9. Sinter machine updraft exhaust leakage							●	●	●				•		•		
10. Sinter return handling					●										•		
11. Sinter machine discharge and screens					x		x	x			●		●		●		
12. Sinter crushing					x		x	x			●		●		●		
13. Sinter transfer to dump area					●		●										
14. Sinter product dump area					•								•		•		
15. Charge car or conveyor loading and transfer of sinter					•		x										
16. Blast furnace - monitor (total)																	
16a. Charging											●	●			●		
16b. Blow condition						x	x	x									
16c. Upset						x	x										
16d. Tapping											●	●			●		
17. Lead pouring to ladle and transfer											●	●			●		
18. Slag pouring											●	●			●		
19. Slag cooling		✓			•						•		•		•		
20. Slag granulator and slag piling		✓		•	•												
21. Zinc fuming furnace vents		✓								•			•		•		
22. Dross kettle											●	●			●		
23. Reverberatory furnace leakage							x	●									
24. Silver retort building		✓											•		•		
25. Lead casting											●	●			●		

x Typical control technique.

● In use (but not typical) control technique.

• Technically feasible control technique.

CONTROL TECHNIQUES FOR
PRIMARY ZINC PRODUCTION IPFPE SOURCES

			FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
Industry: Primary Zinc Production	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system	Minimize free-fall distance (chute or other device)	Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	ESP
1. Railroad car or truck unloading																	
1a. Zinc ore concentrate			✓														
1b. Sand			✓														
1c. Coke			✓														
2. Zinc ore concentrate																	
2a. Storage		✓	✓														
2b. Handling and transfer		✓	✓														
3. Sand																	
3a. Storage		✓	✓														
3b. Handling and transfer		✓	✓														
4. Coke																	
4a. Storage		✓	✓														
4b. Handling and transfer		✓	✓														
5. Sinter machine windbox discharge				+	+					+	+				+		
6. Sinter machine discharge and screens					x		x	x			●		●		●		
7. Coke-sinter mixer					x		x	x			●		●		●		
8. Retort furnace building		✓									+		+		+		
8a. Retort furnace tapping											+	+	+		+		
8b. Retort furnace residue discharge and cooling											+	+	+		+		
8c. Retort furnace upset		✓					x					+			+		
9. Zinc casting											●	●			●		

x Typical control technique.

● In use (but not typical) control technique.

+ Technically feasible control technique.

CONTROL TECHNIQUES FOR
SECONDARY ALUMINUM SMELTERS IPFPE SOURCES

			FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
Industry: Secondary Aluminum Processing	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system		Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	Afterburner
1. Sweating furnace						+					x				x		x
2. Crushing and screening scrap metal											+	+	+				
3. Chip (rotary) dryer								●	+								
4. Smelting (reverberatory) furnace											x		+		x		
5. Smelting (crucible) furnace						+					x		●		x		
6. Smelting (induction) furnace											x		+		x		
7. Fluxing (chlorination)											+				x	x	
8. Hot dross handling and cooling											+	+			+		
9. Pouring hot metal into molds or crucible	✓																

x Typical control technique.

● In use (but not typical) control technique.

+ Technically feasible control technique.

CONTROL TECHNIQUES FOR
SECONDARY COPPER, BRASS/BRONZE PRODUCTION IPFPE SOURCES

Industry: Secondary Copper, Brass/Bronze Production			FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system		Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	ESP
1. Sweating furnace																	
1a. Charging								+	+		o	+	+		o		
1b. Tapping							o	+	+		o	+	+		o		
2. Drying																	
2a. Charging											+	+	+		+		
2b. Discharging											+	+	+		+		
3. Insulation burning									+								
4. Electric induction furnace																	
4a. Charging											o	+	+		o		
4b. Tapping							o	+	+		o	+	+		o		
5. Reverberatory furnace																	
5a. Charging											o	+	+		o		
5b. Tapping							o	+	+		o	+	+		o		
6. Rotary furnace																	
6a. Charging											o	+	+		o		
6b. Tapping							o	+	+		o	+	+		o		
7. Crucible furnace																	
7a. Charging											o	+	+		o		
7b. Tapping							o	+	+		o	+	+		o		
8. Cupola (blast) furnace																	
8a. Charging											o	+	+		o		
8b. Tapping							o	+	+		o	+	+		o		
9. Casting							o				o	+	+		o		

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

CONTROL TECHNIQUES FOR
FOUNDRY IPFPE SOURCES

			FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
Industry: Foundries	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system		Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	Cyclone
1. Raw material receiving and storage			✓														
2. Cupola furnace operation		✓							+		+	+	+		+	+	
3. Crucible furnace operation											x		+		x		
4. Electric arc furnace operation											x	o	+		x		
5. Open hearth furnace operation											+	+	+		+		
6. Electric induction furnace operation											x		+		x		
7. Pot furnace operation											x	o	+		x		
8. Reverberatory furnace operation											x[a]		+		x		
9. Ductile iron innoculation											x[a]		x[a]		x	x	
10. Pouring molten metal into molds											x	o	+		+	x	
11. Casting shakeout											x	+	+		+	x	
12. Cooling and cleaning castings											x		+		x		x
13. Finishing castings											x				x		x
14. Core sand and core binder receiving and storage													o				
15. Core sand and binder mixing											+				+		
16. Core making		✓									+				+		
17. Core baking		✓				o	o				+					+	
18. Mold sand and binder receiving and storage												o			o	o	
19. Sand preparation												o			o	o	
20. Mold making												o			o	o	

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

[a] Typical for newer installations. For ductile iron innoculation evacuation is more of a local type evacuation rather than entire building evacuation.

CONTROL TECHNIQUES FOR
SECONDARY LEAD SMELTING IPFPE SOURCES

Industry: Secondary Lead Smelting			FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes						Capture methods				Removal equipment		
	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system		Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	ESP
1. Railroad car and truck unloading																	
Coke			✓														
Limestone			✓														
Lead scrap			✓														
Iron scrap			✓														
2. Coke																	
2a. Storage		✓	✓														
2b. Handling and transfer		✓	✓														
3. Limestone																	
3a. Storage		✓	✓														
3b. Handling and transfer		✓	✓														
4. Lead scrap																	
4a. Storage	✓																
4b. Handling and transfer	✓																
5. Iron scrap																	
5a. Storage	✓																
5b. Handling and transfer	✓																
6. Lead and iron scrap burning						+	o	+	o								
7. Sweating furnace																	
7a. Charging											+	+	+		+		
7b. Tapping							o				+	+	+		+		
8. Reverberatory furnace																	
8a. Charging											+	+	+		+		
8b. Tapping							o				+	+	+		+		

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

CONTROL TECHNIQUES FOR
SECONDARY LEAD SMELTING IPFPE SOURCES
(concluded)

			FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
Industry: Secondary Lead Smelting	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system		Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	ESP
9. Blast or cupola furnace																	
9a. Charging											+	+	+		+		
9b. Lead tapping to holding pot							o				+	+	+		+		
9c. Slag tapping											+	+	+		+		
10. Tapping of holding pot							o				+	+	+		+		
11. Pot (kettle) furnace																	
11a. Charging							o				+	+	+		+		
11b. Tapping											+	+	+		+		
12. Casting							o				+		+		+		

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

CONTROL TECHNIQUES FOR
SECONDARY ZINC PRODUCTION IPFPE SOURCES

Industry: Secondary Zinc Production			FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system		Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	ESP
1. Crushing/screening of residue skimmings							o	o			o		+		o		
2. Reverberatory sweat furnace																	
2a. Charging									o		o	o	+		o		
2b. Tapping									o		o	o	+		o		
3. Kettle (pot) sweat furnace																	
3a. Charging									o		o	o	+		o		
3b. Tapping									o		o	o	+		o		
4. Rotary sweat furnace																	
4a. Charging									o		o	o	+		o		
4b. Tapping									o		o	o	+		o		
5. Muffle sweat furnace																	
5a. Charging									o		o	o	+		o		
5b. Tapping									o		o	o	+		o		
6. Electric resistance sweat furnace																	
6a. Charging									o		o	o	+		o		
6b. Tapping									o		o	o	+		o		
7. Hot metal transfer to melting furnace		✓											+		+		
8. Crucible melting furnace																	
8a. Charging									o		o	o	+		o		
8b. Tapping									o		o	o	+		o		
9. Kettle (pot) melting furnace																	
9a. Charging									o		o	o	+		o		
9b. Tapping									o		o	o	+		o		

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

CONTROL TECHNIQUES FOR SECONDARY ZINC PRODUCTION IPFPE SOURCES (concluded)

Industry: Secondary Zinc Production				FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS													
				Preventative procedures and operating changes							Capture methods				Removal equipment		
	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system		Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	ESP
10. Reverberatory melting furnace																	
10a. Charging									o		o	o	+		o		
10b. Tapping									o		o	o	+		o		
11. Electric induction melting furnace																	
11a. Charging									o		o	o	+		o		
11b. Tapping									o		o	o	+		o		
12. Hot metal transfer to retort or alloying		✓											+		+		
13. Distillation retort and condenser																	
13a Charging distillation retort											o	o	+		o		
13b. Leakage between retort and condenser								o			o	o	+		o		
13c. Upset in condenser							o				o	o	+		o		
13d. Tapping											o	o	+		o		
14. Muffle distillation furnace and condenser																	
14a. Charging muffle distillation furnace											o	o	+		o		
14b. Leakage between furnace and condenser								o			o	o	+		o		
14c. Upset in condenser							o				o	o	+		o		
14d. Tapping											o	o	+		o		
15. Alloying											+	+	+		+		
16. Casting							o				+	+	+		+		

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

CONTROL TECHNIQUES FOR
LIME MANUFACTURING IPFPE SOURCES

Industry: Lime Manufacturing			FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure - partial or complete	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system	Choked feed	Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation	Filling spout with outer concentric aspiration duct	Fabric filter	Cyclone	Fabric "Sock"
1. Limestone/dolomite charging to primary crusher				o	x												
2. Primary crushing				o	x						o				o	o^c	
3. Transfer points and associated conveying			✓														
4. Primary screening				o	x						o				o		
5. Secondary crushing				o	x						o				o	o^c	
6. Secondary screening				o	x						o				o		
7. Crushed limestone storage			✓														
8. Quicklime screening[a]				o	x						o				o		
9. Quicklime/hydrated lime crushing and pulverizing with leaks from mill and from feed discharge exhaust systems[b]							o	o									
10. Lime product silo vents															o		o
11. Truck, rail, ship/barge loading of quicklime and hydrated lime					x					x	o	o		o			
12. Packaging quicklime and hydrate lime					x					x	o	o		o	o		o

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

[a] Wet suppression limited due to potential impairment of material quality.

[b] Control of feed/discharge ends of grinding mills (typically hooded and exhausted to fabric filters) considered point source control. Fugitive emission are leaks from pick-up points from these systems.

[c] Primary control often in series with fabric filter.

CONTROL TECHNIQUES FOR
PORTLAND CEMENT MANUFACTURING IPFPE SOURCES

Industry: Portland Cement Manufacturing			FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure - partial or complete	Telescopic or ladder type chutes	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system	Choked feed	Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation	Filling spout with outer concentric aspiration duct	Fabric filter	Cyclone	Fabric "sock"
1. Raw material unloading (rail, barge, truck)			✓														
2. Raw material charging to primary crusher				o	x												
3. Primary crusher				o	x						o				o	o	
4. Transfer points and associated conveying			✓														
5. Vibrating screen				o	x						o				o		
6. Secondary crusher				o	x						o				o		
7. Unloading outfall to storage				x	o	o						+			+		
8. Raw material storage			✓		x								+		+		
9. Transfer to conveyor via clamshell			✓														
10. Raw grinding mill and feed/discharge exhaust systems[a]								o	o								
11. Raw blending	✓																
12. Blended material			✓		x								+		+		
13. Coal storage			✓		o								+		+		
14. Transfer of coal to grinding mill			✓														
15. Leakage from coal grinding mills	✓							o									
16. Unloading-clinker/gypsum outfall to storage				o[b]	x	o						+			+		
17. Clinker/gypsum storage					x								+		+		
18. Clinker/gypsum load-out			✓														
19. Finish grinding with leaks from mill and from feed/discharge exhaust systems								o	o								

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

CONTROL TECHNIQUES FOR
PORTLAND CEMENT MANUFACTURING IPFPE SOURCES
(concluded)

Industry: Portland Cement Manufacturing			FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Telescopic or ladder type chutes	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system	Choked feed	Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation	Filling spout with outer concentric aspiration duct	Fabric filter	Cyclone	Fabric "sock"
20. Cement silo vents															o		o
21. Cement loading					x					x	o	o		o	o		
22. Cement packaging					x					x	o	o		o	o		

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

[a] Control of feed/discharge ends of grinding mills (typically controlled by fabric filters) considered point source control. Fugitive emissions are leaks from pick-up points of these systems.

[b] Wet suppression limited due to potential impairment of material quality.

CONTROL TECHNIQUES FOR
CONCRETE BATCHING IPFPE SOURCES

			FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
Industry: Concrete Batching	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system		Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	Fabric "sock"
1. Sand and aggregate storage			✓														
2. Transfer of sand and aggregate to elevated bins			✓														
3. Cement transfer to elevated storage silos[b] and silo vents					x[a]										o		o
4. Weigh hopper loading of cement, sand, and aggregate											o				o	o	
5. Mixer loading of cement, sand, and aggregate (central mix plant)												o			o	o	
6. Loading of transit mix (wet batching) truck	-				x						o	o			o	o	
7. Loading of flat-bed (dry batch) truck					x						o	o			o	o	

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

[a] For bucket elevators.

CONTROL TECHNIQUES FOR
ASPHALTIC CONCRETE MANUFACTURING IPFPE SOURCES

			FUGITIVE EMISSIONS CAPTURE AND CONTROL METHODS														
				Preventative procedures and operating changes							Capture methods				Removal equipment		
Industry: Asphaltic Concrete Manufacturing	Negligible emissions	IPFPE source typically uncontrolled	Control technologies identified in Section 3.3.2	Wet suppression (water and/or chemical)	Confinement by enclosure	Better control of raw material quality	Better control of operating parameters and procedures	Improved maintenance and/or construction program	Increase exhaust rate of primary control system	Wind shields in direction of prevailing wind	Fixed hoods, curtains, partitions, covers, etc.	Movable hoods with flexible ducts	Closed buildings with evacuation		Fabric filter	Scrubber	Cyclone
1. Storage of coarse and fine aggregate			✓														
2. Unloading coarse and fine aggregate to cold bins				o						o							
3. Cold aggregate elevator					x						o				o	o	o[a]
4. Dried aggregate elevator					x						o				o	o	o[a]
5. Screening hot aggregate					x						o				o	o	o[a]
6. Hot aggregate elevator (continuous mix plant)					x						o				o	o	o[a]

x Typical control technique.

o In use (but not typical) control technique.

+ Technically feasible control technique.

[a] Primary control often in series with fabric filter.

APPENDIX A.9*

LISTING OF CHEMICAL DUST SUPPRESSANTS

Appendix A.9 contains two separate listings of chemical suppressants. The first list (page A.9-2, 3 & 4) presents limited information on various chemical suppressants concerning product type, uses, and application rates. The second list (page A.9-5) presents selected soil stabilizing chemicals and their resultant control efficiencies.

The reference to or mention of manufacturers and their products in these two lists does not constitute an endorsement of such manufacturers or their products by the U.S. Environmental Protection Agency.

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*U.S. EPA. Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions. EPA-450/3-77-010. March 1977.

CHEMICAL DUST SUPPRESSANTS, USES, AND APPLICATION RATES

Company/address phone/contact	Product name/ product type	Uses/comments	Density, dilution and application rates
Dow Chemical Co. 2020 Dow Center Midland, Mich. 517-636-1000 Mr. Harold Filter	XFS - 4163L Styrene-Butadiene	Mulches such as straw, wood cellulose fiber, and fiberglass. Used to prevent wind loss of mulches during stabilization periods such as reseeding periods.	8.5 lbs/gal. 40 gallons XFS - 4163L: 360 gallons water 400 gallons/acre
Witco Chemical Corp. Golden Bear Division Post Office Box 378 Bakersfield, Calif. 93302 805-399-9501 Mr. William Canessa	Coherex Cold water emvision of Petroleum Resins	Unpaved haul roads and stockpiles. Can be used around human or animal habitats - very clean - no heat required. Can be stored for 12 months or longer. Must be protected from freezing - unless freeze stable type is used. Can be spread through any type of equipment used to spread water.	8.33 lb/gal. 1:4 dilution, 1-1.5 gal/yd^2 for parking lots and dirt roads. 1:7 dilution 0.5 to 1 gal/yd^2 for thin layer or loose dirt, light traffic, service roads. 1:10 dilution for aid in packing surface
	Semi-pave Cold asphalt cutback with antistrip agent	Penetration of unpaved areas - low traffic volume roads - parking lots etc. Can be handled without heat if ambient temperature is 50°F or higher.	250 gallons/ton 0.6 to 0.9 gal/yd^2
American Cyanamid Wayne, New Jersey 07470 201-831-1234 Mr. L. S. Randolph	Aerospray 52 binder	Seed membrane protection, excavation, construction, slope stabilization	8.8 lb/gallon 2:1 1 gallon/100 ft^2
E. F. Houghton & Co. Valley Forge Tech. Center Madison & Van Buren Ave. Norristown, PA 19401 215-739-7100 Mr. Todd Sutcliffe	Surfax 5107	Coal loading, quarries, cement plants, crushers, sintering plants.	8.5 lb/gallon 1:1000 or higher
	Resosol 5411-B Polymer	Storage piles, railcars, road sides.	8.75 lb/gal 1:30 40 gal/1000 ft^2, recommended 2 applications
Monsanto 800 N. Lindbergh Blvd. St. Louis, MO 63166 314-694-3453 Mr. James A. Cooper	Gelvatol 20-90 Polyvinyl alcohol resin	Surfactant and protective colloid in emulsion polymerization.	30-40 lbs/ft^3 10 to 20 percent by weight
	Gelva Emulsion S-55 Polyvinyl acetate homopolymer	Adhesiver	500 lb/55 gallon drum 1% by weight
Air Products & Chemicals, Inc. 5 Executive Rd. Suedesford Road Wayne, PA 19087	Vinol 540 [illegible]lymer (water soluble)	Two grades: 1) soluble in water (washed away with rain), 2) relatively insoluble in water.	1 to 7 percent by weight Slurried in cold water or heated to insure complete mixture in solution
Union Carbide Corp. West St. & Madisonville Rd Cincinnati, Ohio 45227 513-292-0206 Mr. Wm. Mike Brown	DCA-70	Stabilise steep grades, tailings ponds. Not for vegetation growth.	9.25 lb/gal 2:1

CHEMICAL DUST SUPPRESSANTS, USES, AND APPLICATION RATES

(continued)

Company/address phone/contact	Product name/ product type	Uses/comments	Density, dilution and application rates
Enzymatic Soil of Tucson 6622 N. Los Arboles Cr. Tucson, Arizona 85704 602-297-2133 Mr. Bob Mundell	Enzymatic SS	Hold down dust on haul roads, tailings, stock pile. Will retard growth of weeds or plants. Seal lakes, stock tanks, stabilize odors around stock pens.	8.34 lb/gal 1:1000 1000 gallon/20 to 30 yd^3
Asphalt Rubberizing Corp. 1111 S. Colorado Blvd. Denver, Colorado 80222 303-756-3012 Mr. Jewell Benson	Peneprime Low-viscosity, special hard-base asphalt cutback	Control of wind, rain, or water erosion of soils. Applied to roads and streets to allay dust and stabilize surface to carry traffic. Does not allow seed germination. Very light applications (0.2-0.4 G.S.Y. may accelerate seed germination due to warming of black surface. Applications above 0.4 G.S.Y. inhibit plant growths through hardness and toughness of the crust formed. Plant growths through the crust may be further inhibited by addition of several oil-soluble sterilants. Sterilants kill plant as it emerges. The material may be applied at temperatures as low as 75°F by conventional asphalt distribution equipment.	0.85 S.G. dust abatement - 0.2 gal/yd^2 erosion control - 0.5-1.0 gal/yd^2
Johnson-March Co. 3018 Market St. Philadelphia, PA 19104 215-222-1411 Mr. Sam Jaffe	Compound-MR (regular)	Usually used with a spray system or storage piles, conveying systems.	1:1000 water applied as needed
	Compound-SP-301	Used on haul roads, parking lots, stabilizing cleared areas, aid in vegetation growth.	1 gal/100 ft^2 ± depending on conditions. Application lasts 6 months to a year
	Compound-MR (superconcentrate)	Same as Compound-MR (regular)	1:3500 water
	Compound-SP-400	Same as Compound SP-301	Same as Compound SP-301 Application lasts 1 to 5 years
	Coal Tarp	Designed for use in coal industry: coating over rail cars, trucks to prevent transportation losses etc. Prevents seed germination.	
Grass Growers P. O. Box 584 Plainfield, NJ 07061 201-755-0923 Mr. Elsner	Tarratack-1	Mulch binder used for stabilizing any type of grass to be grown.	5 lb: 250 gal water, mixed with wood fiber mulch (40 lb/acre) 5 lb: 150 gal water, mixed with hay or straw (40 lb/acre)
	Tarratack-2	Same as Tarratack-1	Mixed with hay or straw 40 lb/acre
	Tarratack-3	Same as Tarratack-1	Mixed with wood fiber only

CHEMICAL DUST SUPPRESSANTS, USES, AND APPLICATION RATES

(concluded)

Company/address phone/contact	Product name/ product type	Uses/comments	Density, dilution and application rates
Dubois Chemical Dubois Tower Cincinnati, Ohio 513-762-6000 Mr. Burger	Floculite 600	Used in waste water treatment from mines. Also helps keep down dust on haul roads.	1-2 lb/1000 gal
Mona Industries, Inc. 65 E. 23rd St. Paterson, NJ 07524 201-274-8220 Mr. George Lowry	Monawet Mo-70E	Used in coal industry as dust suppresant	0.1 percent in water, must be reapplied when water evaporates
AMSCO Division Union Oil Company of California 14445 Alomdra Blvd. La Miroda, Calif. 90638 714-523-5120 Dr. Ralph H. Bauer	Res AB 1881 Styrene Butadiene	Soil stabilizer particularly in conjunction with wood fiber malches. Free pumping in conventional hydroseeding equipment. Not to be applied in soils with pH less than 6.0.	8.2 ± 0.1 lb/gallon

SOIL STABILIZING CHEMICALS
AND CONTROL EFFICIENCIES

	Dust Suppression Chemical (water plus as listed)	Control Efficiency (%)
1.	Dustrol "A" 1:5000	-7.8
2.	T-Det 1:4	76
3.	CaO 1%	2.8
4.	$CaCl_2$ 2%	33.8
5.	Cements 5%	26.8
6.	Coherex 1:15	22.5
7.	Coherex 1:8	15.5
8.	Coherex 1:4	97.2
9.	Dowell Chemical Binder 1%	70.4
10.	Dowell Chemical Binder 2%	97.2
11.	Dowell Chemical Binder 3%	97.2
12.	1% $CaCl_2$, in 1:5000 Dustrol "A"	15.5
13.	1% CaO in 1:8 Coherex	31
14.	1% CaO in 2% Dowell Chemical Binder	95.1
15.	1% CaO in 3% Dowell Chemical Binder	81.7
16.	Dried Whole Blood 5%	27.1
17.	Dried Pork Plasma 5%	79
18.	Dried Pork Plasma 3%	96
19.	1% $CaCl_2$ in 3% Pork Plasma	52
20.	Dri-Pro 5%	7
21.	1% CaO, 1:3000 T-Det in 2% Dowell Chemical Binder	98.6
22.	1% CaO, 1% $CaCl_2$, 1:4000 Dustrol "A" + 2% Dowell Chemical Binder	98.6

APPENDIX B.1
UNIT CONVERSION FACTORS

This appendix provides conversion factors to express the emission stream characteristics in the units specified in the calculation procedures. Example calculations are included to illustrate the application of the equations and conversion factors. Table B.1-1 presents a listing of commonly used conversion factors.

Conversion Factors:

Concentration:

From:	To:	
ppmv	volume or mole %	Divide by 10,000
volume fraction	"	Multiply by 100
mole fraction	"	Multiply by 100
mole percent	"	Same as volume (percent)
weight fraction	"	Use the following equation:

$$y_i = 100\,(x_i/MW_i)/\sum_{i=1}^{n}(x_i/MW_i) \qquad (1)$$

where:

y_i = volume or mole percent of component i

x_i = weight fraction of component i

MW_i = molecular weight of component i lb/lb-mole

n = number of components in the emission stream

weight percent	"	Divide by 100 and apply Equation 1

Temperature:

From:	**To**:	
^oC	^oF	Multiply by 1.8 and add 32

Flow rate:

From:	**To**:	
m^3/min	scfm	Multiply by 35.31
lb/min	scfm	Use the following equation: $Q = \underline{m}\ (387/MW_{avg})$ (2) where: Q = flow rate, scfm $\underline{m}$ = flow rate, lb/min MW_{avg} = average molecular weight, lb/lb-mole and the factor 387 denotes the volume occupied by 1 lb-mole of ideal gas at standard conditions. The average molecular weight is expressed as: $MW_{avg} = (1/100) \sum_{i=1}^{n} y_i\ MW_i$ (3)
scfm	lb-mole/min	Divide by 387

Viscosity:

From:	**To**:	
centipoise	lb/ft-hr	Multiply by 2.42

EXAMPLE CASE

The moisture content of an air stream with a flow rate of 5,000 lb/min is 0.05 expressed as weight fraction. (a) What is the moisture content in terms of volume (percent)? (b) What is the flow rate expressed as scfm?

(a) Use Equation 1:

$$y_{H20} = 100\ (x_{H20}/MW_{H20})/[(x_{H20}/MW_{H20}) + (x_{air}/MW_{air})]$$

where:

x_{H_2O} = 0.05

MW_{H_2O} = 18 lb/lb-mole

x_{air} = 0.95

MW_{air} = 29 lb/lb-mole

Then,

y_{H_2O} = 7.8%

(b) Use Equation 3:

$$\begin{aligned} MW_{avg} &= (1/100)\ [(y_{H20} \times MW_{H20}) + (y_{air} \times MW_{air})] \\ &= (1/100)[(7.8 \times 18) + [(100 - 7.8) \times 29]] \\ &= 28.1 \text{ lb/lb-mole} \end{aligned}$$

and

$\underline{m}$ = 5,000 lb/min

Insert the values for MW_{avg} and $\underline{m}$ into Equation 2:

Q = 5,000 (387/28.1)

Q = 68,860 scfm

TABLE B.1-1

CONVERSION FACTORS

From	To	Multiply by
Pascal	Atmosphere (760 mm Hg)	9.870×10^{-6}
Pascal	Pound-force/square inch	1.450×10^{-4}
Centimeter of Hg	Feet of water	0.4460
Pound-force/square feet	Inches of water	0.192
Joule	Btu	9.480×10^{-4}
Joule	Watt-hr	2.778NO
Watt	Horsepower	1.340×10^{-3}
^{o}C	^{o}F	$(^{o}C\times1.8)+32$
^{o}F	^{o}R	$^{o}F+460$
^{o}C	^{o}K	$^{o}C+273$
Meter	Feet	3.28
Meter	Inch	39.37
Square Meter	Square Feet	10.758
Square Meter	Square Inch	1.55×10^{3}
Cubic Meter	Cubic Feet	35.31
Cubic Meter	Gallon (U.S. Liquid)	2.643×10^{2}
Cubic Meter/Second	Gallon/Minute	1.585×10^{4}
Kilogram	Pound-mass	2.205
Centipoise	Pount-force/feet-hr	2.42
Tons (refrigeration)	Btu/hr	12,000

APPENDIX B.2
PROCEDURES FOR CALCULATING GAS STREAM PARAMETERS

At many plants, it is common that one pollution control system is used to serve several emission sources. In such situations, the combined emission stream parameters must be calculated from mass and heat balances. Procedures for calculating the combined emission stream and single emission stream parameters listed below are provided in this appendix.

- Flow Rate and Temperature (Section A)
- Moisture Content, SO_3 Content, and Dew Point (Section B)
- Particulate Matter Loading (Section C)
- Heat Content (Section D)

A. Emission Stream Flow Rate and Temperature Calculations

Only gas volumes at standard conditions (70°F, 1 atm.) can be added together. Thus, volumes of all gas streams must first be converted to volumes at standard conditions. This calculation is shown below. [Note: It is assumed that the emission streams are approximately at atmospheric conditions; therefore, pressure corrections are not necessary.]

$$Q_{e1,a} \times \frac{530}{460 + T_{e1}} = Q_{e1}$$

where: $Q_{e1,a}$ = flow rate of gas stream #1 at actual conditions (acfm)

T_{e1} = temperature of gas stream #1 (°F)

Q_{e1} = flow rate of gas stream #1 at standard conditions (scfm)

This calculation is repeated for each emission stream which, when combined, will be served by the control system. The total gas stream volumetric flow rate at standard conditions (Q_e) is calculated by adding all gas streams, as follows:

$$Q_{e1} + Q_{e2} + \ldots = Q_e$$

where: Q_e = flow rate of combined gas stream (scfm)

The temperature of the combined gas stream (T_e) must be calculated to convert this combined volumetric flow rate at standard conditions (Q_e) to actual conditions ($Q_{e,a}$).

The temperature of the combined gas stream (T_e) is determined by first calculating the enthalpy (sensible heat content) of each individual stream. The calculation procedures are shown below.

$$Q_{e1} \times \frac{0.018\ \text{Btu}}{\text{ft}^3\text{-}^\circ\text{F}} \times (T_{e1} - 70) = H_{s1}$$

where: T_{e1} = temperature of gas stream #1 (°F)

H_{s1} = sensible heat content of gas stream #1 (Btu/min)

This calculation is repeated for each emission stream. The total sensible heat is calculated as follows:

$$H_{s1} + H_{s2} + \ldots = H_s$$

where: H_s = sensible heat of combined gas stream (Btu/min)

The combined gas stream temperature (T_e) is calculated as follows:

$$H_s \times \frac{\text{ft}^3\text{-}^\circ\text{F}}{0.018\ \text{Btu}} \times \frac{1}{Q_e} = T_e$$

where: T_e = temperature of combined gas stream (°F)

The actual combined gas stream volumetric flow rate at actual conditions ($Q_{e,a}$) is then determined as follows:

$$Q_e \times \frac{460 + T_e}{530} = Q_{e,a}$$

where: $Q_{e,a}$ = flow rate of combined gas stream at actual conditions (acfm)

B. Moisture Content, SO_3 Content, and Dew Point Calculations

Moisture content is typically reported as a volume percent. The calculation procedures require that the volume percent moisture content of each stream be converted to a lb-mole basis, added together, and then divided by the total combined gas stream volumetric flow rate (Q_e) to obtain the moisture content of the combined gas stream. The moisture content is calculated below both on a volume percent and mass percent basis. The mass basis is to allow for the dew point calculation.

The moisture content is converted from a vol % basis to a lb-mole basis as follows:

$$M_{e1} \times \frac{1}{100\%} \times Q_{e1} \times \frac{\text{lb-mole}}{414\text{ scf}} = M_{e1,1m}$$

where: M_{e1} = moisture content of gas stream #1 (% vol.)

$M_{e1,1}$ = moisture content of gas stream #1 (lb-mole/min)

This calculation is repeated for each emission stream to be combined. The moisture content of the combined gas stream on a volume percent basis (M_e) is calculated by adding, as follows:

$$M_{e1,1m} + M_{e2,1m} + \ldots = M_{e,1m}$$

$$M_{e,1m} \times \frac{414\text{ scf}}{\text{lb-mole}} \times \frac{1}{Q_e} \times 100\% = M_e$$

where: $M_{e,1m}$ = moisture content of combined gas stream (lb-mole/min)

M_e = moisture content of combined gas stream (% vol)

The moisture content of the combined stream must be reported on a mass basis ($M_{e,m}$) to determine the dew point. This is calculated as follows:

$$M_{e,1m} \times \frac{18\text{ lb}}{\text{lb-mole}} = M_{e,m}$$

where: $M_{e,m}$ = moisture content of combined gas stream (lb/min)

The amount of dry air in the combined gas stream (DA_e) is calculated as follows:

$$Q_e \times \frac{\text{lb-mole}}{414\text{ scf}} \times \frac{29\text{ lb}}{\text{lb-mole}} = DA_e$$

where: DA_e = dry air content of combined gas stream (lb/min)

Calculate the psychometric ratio as follows:

$$M_{e,m}/(DA_e - M_{e,m}) = \text{psychrometric ratio (lb of water/lb dry air)}$$

Knowing the psychrometric ratio and the gas stream temperature, the dew point temperature is selected from Table B.2-1.

The presence of sulfur trioxide (SO_3) in the gas stream increases the dew point of the stream. If the SO_3 component is ignored during the dew point determination, condensation may occur when not expected. In addition to the problems associated with the entrainment of liquid droplets in the gas steam, the SO_3 will combine with the water droplets to form sulfuric acid, which causes severe corrosion on metal surfaces and deterioration of many fabrics used in baghouses. Therefore, the determination of the stream dew point must consider the presence of SO_3. With information on the SO_3 content (ppm vol.) and the moisture content (% vol.) of the gas stream, the "acid" dew point temperature can be determined from Figure B.2-1. Figure B.2-1 provides dew points for two moisture levels, however, dew points can be estimated for other moisture values.

The SO_3 content of a combined gas stream is calculated by first converting the SO_3 concentration of each individual stream to a lb-mole basis. The SO_3 content is calculated as follows:

$$S_{e1} \times \frac{1}{10^6} \times Q_{e1} \times \frac{\text{lb-mole}}{414 \text{ scf}} = S_{e1,lm}$$

where: S_{e1} = SO_3 content of gas stream #1 (ppm vol.)

$S_{e1,lm}$ = SO_3 content of gas stream #1 (lb-mole/min)

This is repeated for each separate gas stream. These are then added to obtain the total SO_3 content of the combined gas stream to the control device as follows:

$$S_{e1,lm} + S_{e2,lm} = \ldots = S_{e,lm}$$

$$S_{e,lm} \times \frac{414 \text{ scf}}{\text{lb-mole}} \times \frac{10^6}{Q_e} = S_e$$

where: $S_{e,lm}$ = SO_3 content of combined gas stream (lb-mole/min)

S_e = SO_3 content of combined gas stream (ppm vol.)

TABLE B.2-1 DEW POINT TEMPERATURES

Psychometric Ratio	Gas Stream Temperatures (°F)										
	70	80	90	100	120	140	160	180	200	220	240
	Dew Point Temperatures (°F)										
0.000	0	0	0	0	0	0	0	0	0	0	0
0.005	54	58	61	65	70	76	81	86	89	93	96
0.010	62	65	68	71	77	82	86	90	94	97	100
0.015	68	72	75	77	82	86	90	94	97	100	103
0.020		77	80	82	87	91	94	97	100	103	106
0.025			85	87	91	94	98	101	103	106	109
0.030			89	91	95	98	100	104	107	109	111
0.035				95	98	101	104	107	109	110	114
0.040				98	101	104	107	109	111	114	116
0.045					104	107	109	112	114	116	118
0.050					107	109	112	114	116	118	120
0.055					109	112	114	116	118	120	122
0.060					111	114	116	118	120	122	124
0.065					114	116	118	120	122	124	125
0.070					116	118	120	122	123	125	130
0.075					118	120	122	124	125	130	150
0.080					119	122	123	125	130	140	170
0.085						123	125	130	143	168	182
0.090						124	130	140	162	180	205
0.095						128	140	165	180	205	225

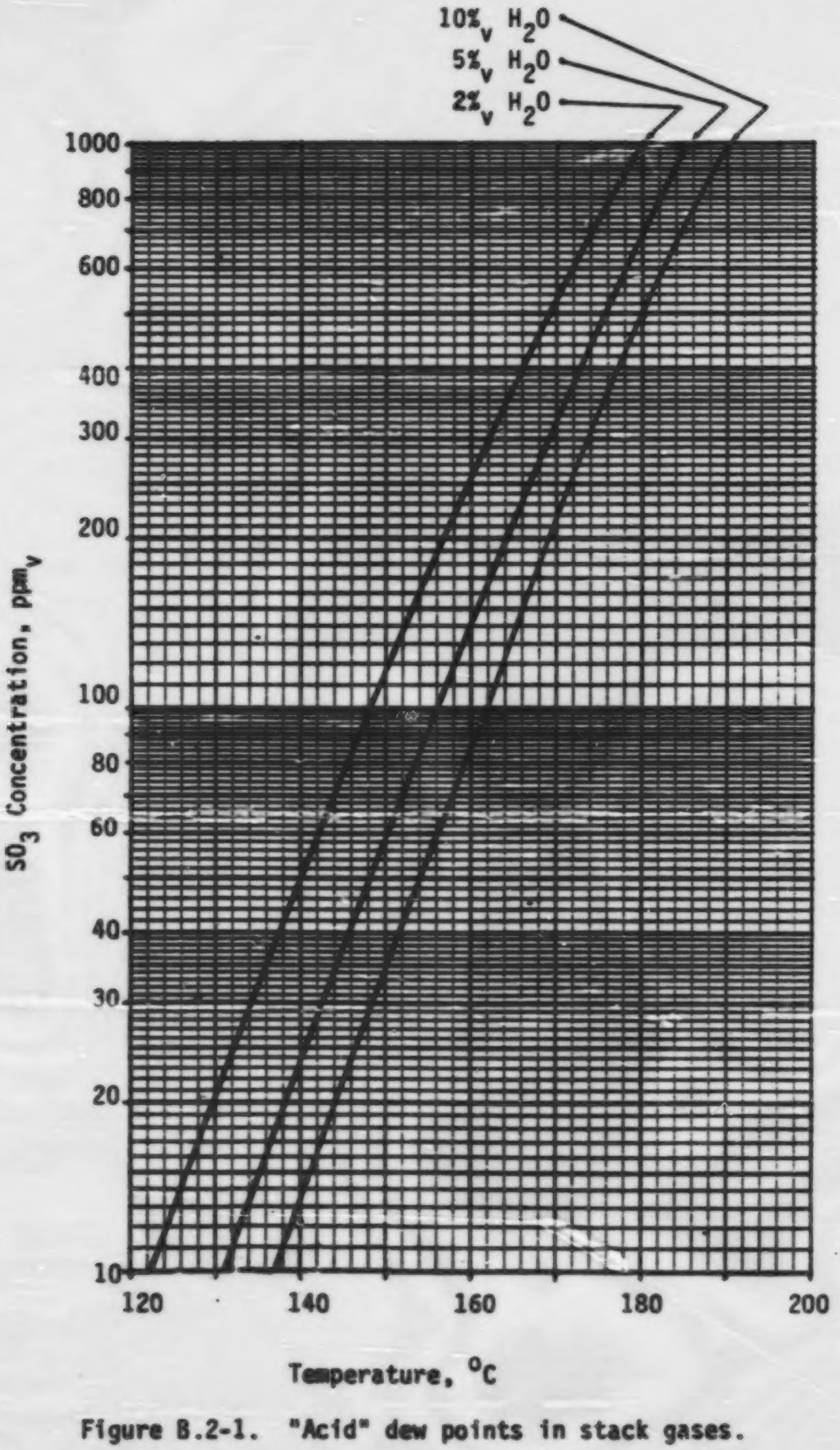

Figure B.2-1. "Acid" dew points in stack gases.

With information for the SO_3 content of the combined gas stream (S_e) and the moisture content of the combined gas stream (M_e), the acid dew point is determined from Figure B.2-1.

C. Particulate Matter Loading

Particulate matter concentrations usually are reported in grains per acf. The procedures below may be used to determine the particulate loading to a control device (in lbs/hr) when gas streams are combined.

$$W_{e1,g} \times Q_{e1,a} \times \frac{60 \text{ min}}{\text{hr}} \times \frac{\text{lb}}{7{,}000 \text{ gr}} = W_{e1,l}$$

where: $W_{e1,g}$ = particulate loading for gas stream #1 (gr/acf)

$W_{e1,l}$ = particulate loading for gas stream #1 (lb/hr)

This is repeated for each gas stream and the results are added to obtain the particulate loading for the combined gas stream.

$$W_{e1,l} + W_{e2,l} + \ldots = W_{e,l}$$

where: $W_{e,l}$ = particulate loading for combined gas stream (lb/hr)

The particulate loading of the combined gas stream can be converted to a concentration as follows:

$$W_{e,l} \times \frac{7{,}000 \text{ gr}}{\text{lb}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{1}{Q_{e,a}} = W_{e,g}$$

where: $W_{e,g}$ = particulate loading for combined gas stream (gr/acf)

D. Heat Content Calculation

The heat content of gas stream #1 (h_{e1}) can be determined from the heat of combustion of its components using the following equation:

$$h_{e1} = (0.01) \sum_{i=1}^{n} y_{e1,i} \times h_{e1,i}$$

where: h_{e1} = heat content in gas stream #1 (Btu/scf)

$y_{e1,i}$ = volume percent of component "i" in gas stream #1 (% vol.)

$h_{e1,i}$ = heat of combustion of component "i" in gas stream #1: see Table B.2-2 (Btu/scf)

n = number of components in gas stream #1

TABLE B.2-2. HEATS OF COMBUSTION AND LOWER EXPOSIVE LIMIT (LEL) DATA FOR SELECTED COMPOUNDS[a]

Compound	LEL (ppmv)	Net Heat of Combustion[b,c] (Btu/scf)
Methane	50,000	892
Ethane	30,000	1,588
Propane	21,000	2,274
n-Butane	16,000	2,956
Isobutane	18,000	2,947
n-Pentane	15,000	3,640
Isopentane	14,000	3,631
Neopentane	14,000	3,616
n-Hexane	11,000	4,324
Ethylene	27,000	1,472
Propylene	20,000	2,114
n-Butene	16,000	2,825
1-Pentene	15,000	3,511
Benzene	13,000	3,527
Toluene	12,000	4,196
Xylene	11,000	1,877
Acetylene	25,000	1,397
Naphthalene	9,000	5,537
Methyl alcohol	60,000	751
Ethyl alcohol	33,000	1,419
Ammonia	160,000	356
Hydrogen sulfide	40,000	583

[a] Sources: Steam/Its Generation and Use. The Babcock & Wilcox Company. New York, NY. 1975.

Fire Hazard Properties of Flammable Liquids, Gases, Volatile Solids - 1977. National Fire Protection Association. Boston, MA. 1977.

[b] Lower heat of combustion.

[c] Based on 70°F and 1 atm.

The heat content of a combined emission stream can be determined from the heat content of the individual emission streams as follows:

$$h_e = (0.01) \sum_{j=1}^{m} y_{ej} \times h_{ej}$$

where: h_e = combined emission stream heat content (Btu/scf)

y_{ej} = volume percent of stream "j" in combined gas stream (% vol.)

h_{ej} = heat content of stream "j" in combined gas stream: see previous discussion (Btu/scf)

m = number of individual gas streams in combined gas stream

EXAMPLE CASE

Calculate the heat content of an emission stream from a paper coating operation (gas stream #1) with the following composition data: methane (44 ppmv), toluene (73 ppmv), and others (4 ppmv). Let subscripts "1" and "2" denote methane and toluene, respectively.

$$h_{e1} = (0.01)\ (y_{e1,1} \times h_{e1,1} + y_{e1,2} \times h_{e1,2})$$

Convert the concentrations to volume percent basis:

Methane: $y_{e1,1}$ = 0.0048 (assume "others" is equivalent to methane)

Toluene: $y_{e1,2}$ = 0.0073

From Table B.2-2:

Methane: $h_{e1,1}$ = 892 Btu/scf

Toluene: $h_{e1,2}$ = 4,196 Btu/scf

Substituting these values in the above equation yields:

$$h_{e1} = 0.35 \text{ Btu/scf}$$

TABLE B.2-3 PROPERTIES OF SELECTED ORGANIC COMPOUNDS[a]

Compound	Molecular Weight (lb/lb-mole)	Boiling Point (°F)
Acetone	58	133
Benzene	78	176
n-Butyl acetate	116	257
n-Butyl alcohcl	74	243
Carbon tetrachloride	154	170
Chloroform	119	142
Cyclohexane	54	176
Ethyl acetate	88	171
Ethyl alcohol	46	173
Heptane	100	209
Hexane	86	156
Isobutyl alcohol	74	225
Isopropyl acetate	103	191
Isopropyl alcohol	60	181
Methyl acetate	74	135
Methyl alcohol	32	148
Methylene chloride	85	104
Methyl ethyl ketone	72	175
Methyl isobutyl ketone	100	244
Perchloroethylene	166	250
Toluene	92	231
Trichlorethylene	131	189
Trichlorotrifluoroethane	187	118
Xylene	106	281-292

[a] Source: Chemical Engineer's Handbook. Perry, R.H. and Chilton, C.H. (eds). Fifth Edition. McGraw-Hill Book Company. New York, NY. 1973.

APPENDIX B.3

DILUTION AIR REQUIREMENTS

This appendix describes the calculation procedure used in determining dilution air requirements.

Dilution Air Calculations

The quantity of dilution air (Q_d) needed to decrease the heat content of the emission stream to h_d is given by the following equation:

$$Q_d = [(h_e/h_d) - 1]Q_e \qquad (1)$$

where:

Q_d = dilution air flow rate, scfm
h_e = emission stream heat content before dilution, Btu/scf
h_d = emission stream heat content after dilution, Btu/scf
Q_e = emission stream flow rate before dilution, scfm

The concentrations of the various components and flow rate of the emission stream have to be adjusted after dilution as follows:

$$O_{2,d} = O_2\,(h_d/h_e) + 21\,[1 - (h_d/h_e)] \qquad (2)$$

$$M_{e,d} = M_e\,(h_d/h_e) + 2\,[1 - (h_d/h_e)] \qquad (3)$$

$$Q_{e,d} = Q_e\,(h_e/h_d) \qquad (4)$$

where:

$O_{2,d}$ = oxygen content of diluted emission stream, volume percent
$M_{e,d}$ = moisture content of diluted emission stream, volume percent
$Q_{e,d}$ = flow rate of the diluted emission stream, scfm

The factor "21" in Equation 2 denotes the volumetric percentage of oxygen in air and the factor "2" in Equation 3 is the volumetric percentage of moisture in air at 70°F and 80 percent humidity.

After dilution, the HAP emission stream characteristics are redesignated as follows:

$O_2 = O_{2,d} =$ __________ %
$M_e = M_{e,d} =$ __________ %
$h_e = h_d =$ __________ Btu/scf
$Q_e = Q_{e,d} =$ __________ scfm

APPENDIX B.4

THERMAL INCINERATOR CALCULATIONS

This appendix describes the derivation of the equations used in calculating supplementary fuel requirements (Q_f), additional combustion air requirements (Q_c), and resulting flue gas (Q_{fg}). It also describes how the various parameters in the equations are to be determined and discusses the application of the equations. Standard conditions assumed are: 70°F and 1 atmosphere.

Derivation:

For a given combustion temperature (T_c), the quantity of heat needed to maintain the combustion temperature in a thermal incinerator (H_c) is provided by: (a) the heat generated from the combustion of supplementary fuel (H_f), (b) the heat generated due to the combustion of hydrocarbons in the emission stream (H_e), (c) the sensible heat contained in the emission stream as it leaves the emission source (H_s), and (d) the heat gained by the emission stream through heat exchange (H_{he}). Thus,

$$H_c = H_f + H_e + H_s + H_{he} \tag{1}$$

Each term in Equation (1) is expanded as follows:

A. The heat supplied by the supplementary fuel (H_f) is equal to the flow rate of the fuel (Q_f) multiplied by its heating value (h_f) as follows:

$$H_f = Q_f h_f \tag{2}$$

B. The heat generated due to the combustion of the hydrocarbons in the emission stream (H_e) can be calculated from the flow rate of the emission stream (Q_e) and its heat content (h_e) as follows:

$$H_e = Q_e h_e \tag{3}$$

C. The sensible heat content of the emission stream as it leaves the process and before it enters the thermal incinerator system (H_s) is expressed as:

$$H_s = Q_e \, Cp_e \, (T_e - T_r) \qquad (4)$$

where:

Cp_e = average specific heat of the emission stream (based on the temperature interval T_r to T_e), Btu/scf-°F
T_e = temperature of the emission stream, °F
T_r = reference temperature, = 70°F

The average specific heat for the emission stream over a given temperature interval can be determined from the average specific heat of its components (Cp_i) using the following expression:

$$Cp_e = (1/100) \sum_{i=1}^{n} y_i Cp_i \qquad (5)$$

where:

y_i = volume (percent) of component i in the emission stream
Cp_i = average specific heat of component i, Btu/scf-°F
n = number of components in the emission stream

Values for Cp_i can be obtained from Table B.4-1 where average specific heat data for several compounds are presented as a function of temperature. As an approximation, the average specific heat of the emission stream can be assumed to equal the average specific heat of air containing water vapor over the same temperature range.
Since $Cp_{water} \simeq 1.2 \, Cp_{air}$ over the temperature range 70-2,200°F, Cp_e can be approximated as:

$$Cp_e = [1 + 0.2 \, (M_e/100)] \, Cp_{air} = (1 + 0.002 \, M_e) \, Cp_{air} \qquad (6)$$

where:

M_e = moisture content of the emission stream, volume percent

TABLE B.4-1. AVERAGE SPECIFIC HEATS OF VAPORS[a,b]

Average Specific Heat, Cp (Btu/scf-°F)[c,d]

Temperature (°F)	Air	H_2O	O_2	N_2	CO	CO_2	H_2	CH_4	C_2H_4	C_2H_6
77	0.0180	0.0207	0.0181	0.0180	0.0180	0.0230	0.0178	0.0221	0.0270	0.0326
212	0.0181	0.0209	0.0183	0.0180	0.0180	0.0239	0.0179	0.0232	0.0293	0.0356
392	0.0181	0.0211	0.0186	0.0181	0.0181	0.0251	0.0180	0.0249	0.0324	0.0395
572	0.0183	0.0212	0.0188	0.0182	0.0183	0.0261	0.0180	0.0266	0.0353	0.0432
752	0.0185	0.0217	0.0191	0.0183	0.0184	0.0270	0.0180	0.0283	0.0379	0.0468
932	0.0187	0.0221	0.0194	0.0185	0.0186	0.0278	0.0181	0.0301	0.0403	0.0501
1,112	0.0189	0.0224	0.0197	0.0187	0.0188	0.0286	0.0181	0.0317	0.0425	0.0532
1,292	0.0191	0.0228	0.0199	0.0189	0.0190	0.0292	0.0182	0.0333	0.0445	0.0560
1,472	0.0192	0.0232	0.0201	0.0190	0.0192	0.0298	0.0182	0.0348	0.0464	0.0587
1,652	0.0194	0.0235	0.0203	0.0192	0.0194	0.0303	0.0183	0.0363	0.0481	0.0612
1,832	0.0196	0.0239	0.0205	0.0194	0.0196	0.0308	0.0184	0.0376	0.0497	0.0635
2,012	0.0198	0.0243	0.0207	0.0196	0.0198	0.0313	0.0185	0.0389	0.0512	0.0656
2,192	0.0199	0.0246	0.0208	0.0197	0.0199	0.0317	0.0186	0.0400	0.0525	0.0676

[a] Source: Reference 1.

[b] Average for the temperature interval 77°F and the specified temperature.

[c] Based on 70°F and 1 atm.

[d] To convert to Btu/lb-°F basis, multiply by 387 and divide by the molecular weight of the compound.

The value for Cp_{air} will be based on T_e when Equation 6 is substituted in Equation 4. This approximation introduces relatively insignificant error into the results.

D. The sensible heat content of the emission stream after heat exchange with the flue gas (H_{he}) can be expressed as:

$$H_{he} = Q_eCp_e (T_{he}-T_r) - Q_eCp_e (T_e-T_r) \simeq Q_eCp_e (T_{he}-T_e) \qquad (7)$$

where:

T_{he} = temperature of the emission stream exiting the heat exchanger, ^oF.

The value for Cp_e in the first term is based on the temperature interval T_r to T_{he} and that for the second term is based on the interval T_r to T_e. For simplification purposes, Equation 6 can be subsituted in Equation 7.

E. The quantity of heat needed to maintain the combustion temperature in the incinerator chamber (H_c) is equal to the quantity of heat needed to raise the flue gas to the combustion temperature (T_c); H_c can be expressed as:

$$H_c = Q_{fg} Cp_{fg} (T_c - T_r) \qquad (8)$$

where:

Cp_{fg} = average specific heat of the flue gas (based on the temperature interval T_r to T_c), Btu/scf-^oF

Cp_{fg} can be determined from Equation 5 (replace Cp_e with Cp_{fg} and use Table B.4-1), or it can be approximated by assuming Cp_{fg} is equal to the average specific heat of air containing water vapor over the same temperature range if the composition of the flue gas is known. Cp_{fg} can be expressed as:

$$Cp_{fg} = (1 + 0.002\ M_{fg})\ Cp_{air} \qquad (9)$$

where:

M_{fg} = moisture content of the flue gas, volume percent

F. The flue gas flow rate (Q_{fg}) is determined from the emission stream flow rate (Q_e), supplementary fuel (natural gas) flow rate (Q_f), and additional air flow rate required for combustion of the supplementary fuel and hydrocarbons in the emission stream (Q_c).

$$Q_{fg} = Q_e + Q_f + Q_c \tag{10}$$

G. The additional combustion air requirement (Q_c) is a function of the heat content (h_e) of the emission stream, the concentration of oxygen (O_2) in the emission stream, and the amount of supplementary fuel (Q_f) needed to attain the desired combustion temperature (T_c). The total amount of air required equals:

1. Air required for combustion of hydrocarbons in the emission stream ($Q_{c,1}$): Since this quantity depends on the actual composition and concentration of the hydrocarbons in the emission stream, a rule of thumb can be used: 1 scf of air is required during combustion for every 100 Btu's of heat generated. Thus, the air required can be expressed as:

$$Q_{c,1} = 0.01\ H_e$$

2. Air required for combustion of supplementary fuel ($Q_{c,2}$): Assume natural gas with the following properties as the supplementary fuel:[2]

Composition:

CH_4: 90% (volume)
C_2H_6: 5% (volume)
N_2: 5% (volume)

Lower heating value: 882 Btu/scf

The combustion reaction can be represented as follows:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$
$$C_2H_6 + 3.5\ O_2 \rightarrow 2CO_2 + 3H_2O$$

1 scf of CH_4 requires 2 scf of O_2 and 2 scf of O_2 is equivalent to 2 x (100/21) = 9.52 scf of air. Similarly, 1 scf of C_2H_6 requires 3.5 x (100/21) = 16.67 scf of air. For natural gas with the above composition, the total amount of air required for Q_f is:

$$Q_{c,2} = (0.9 \times 9.52 + 0.05 \times 16.67)\ Q_f$$
$$Q_{c,2} = 9.4\ Q_f$$

3. Excess air to ensure complete combustion ($Q_{c,3}$):

$$Q_{c,3} = (0.01\ H_e + 9.4\ Q_f)\ (0.01\ ex)$$

where:

ex = percent excess air.

Therefore, the total amount of air required can be expressed as a summation of the three terms discussed above:

$$Q_{c,1} + Q_{c,2} + Q_{c,3} = (0.01\ H_e + 9.4\ Q_f)(1 + 0.01\ ex) \quad (11)$$

At this point, the amount of oxygen available in the emission stream must be taken into account when calculating the combustion air requirement. The quantity of air that corresponds to the oxygen concentration in the emission stream is $[(O_2/100)\times(100/21)Q_e] = 0.0476\ O_2Q_e$. Since this quantity is available for combustion, the additional combustion air requirement (Q_c) is the total amount of air required from Equation 11 less the amount of air available in the emission stream. Thus,

$$Q_c = (0.01\ H_e + 9.4\ Q_f)\ (1 + 0.01\ ex) - 0.0476\ O_2Q_e \quad (12)$$

Since the percentage of C_2H_6 in natural gas is small, assume that the combustion of natural gas does not lead to an increase in volume. 1 scf of natural gas with 9.40 scf of air produces 10.43 scf of flue gas, an increase of less than 0.3 percent in volume. Also, since emission streams treated by thermal incineration are typically dilute mixtures of VOC and air, assume that the combustion of the VOC in the emission stream does not lead to an increase in volume.

The emission streams treated by thermal incineration generally contain significant quantities of oxygen. In such cases, the combustion air requirement is zero and the flue gas flow rate is expressed as:

$$Q_{fg} = Q_e + Q_f \qquad (13)$$

Substituting Equations 2, 3, 4, 6, 8, and 13 into Equation 1 and solving for Q_f yields the following expression:

$$Q_f = Q_e\left[\frac{[Cp_{fg}\ (T_c-T_r) - Cp_e\ (T_{he}-T_r) - h_e]}{h_f-Cp_{fg}\ (T_c-T_r)}\right] \qquad (14)$$

If the combustion air requirement is greater than zero (e.g., process emissions), then the flue gas flow rate (Q_{fg}) can be expressed as:

$$Q_{fg} = Q_e + Q_f + [(0.01H_e+9.4Q_f)(1+0.01ex) - 0.0476\ 0_2Q_e] \qquad (15)$$

Substituting Equations 2, 3, 4, 6, 8, and 15 into Equation 1 and solving for Q_f yields the following expression:

$$Q_f = Q_e\left[\frac{[1 + 0.01h_e\ (1+0.01\ ex)-0.0476\ 0_2]Cp_{fg}(T_c-T_r)-Cp_e(T_{he}-T_r)-h_e}{h_f - [10.4 + 0.094\ ex)]\ Cp_{fg}\ (T_c-T_r)}\right] \qquad (16)$$

Simplification of Equations 14 and 16:

As indicated earlier, Cp_e and Cp_{fg} can be calculated using Equation 5 if the composition of each stream is known. As an approximation, Equations 6 and 9 can be substituted in Equations 14 and 16 for Cp_e and Cp_{fg}, respectively.

The value for M_e will be available from input data. The term M_{fg} can be calculated as follows. The moisture in the flue gas is due to the moisture entering the system with the emission stream and combustion air and the moisture generated as a result of combustion.

1. Moisture in the emission stream (Mo_1):

$$Mo_1 = 0.01\ Q_e\ M_e$$

2. Moisture in the combustion air (Mo_2): Assume the moisture content of combustion air is M_c (volume, percent):

$$Mo_2 = 0.01\ Q_c\ M_c$$

3. Moisture generated from supplementary fuel (natural gas) combustion (Mo_3): 2 scf of H_2O is generated from combustion of 1 scf of CH_4 and 3 scf of H_2O is generated from combustion of 1 scf of C_2H_6.

$$Mo_3 = (0.90 \times 2)+(0.05 \times 3)\ Q_f = 1.95\ Q_f$$

4. Moisture formed from combustion of hydrocarbons in the emission stream (Mo_4): Assume that the amount of moisture formed is equivalent to 15 percent of the theoretical combustion air requirement.

$$Mo_4 = (0.01\ H_e)\ 0.15 = 0.0015\ H_e$$

The total moisture in the flue gas is:

$$\sum_{i=1}^{4} Mo_i = 0.01\ M_e\ Q_e + 0.01\ M_c\ Q_c + 1.95\ Q_f + 0.0015\ H_e$$

Hence, M_{fg} can be expressed as:

$$M_{fg} = 100\left[\frac{0.01\ M_eQ_e + 0.01\ M_cQ_c + 1.95\ Q_f + 0.0015\ H_e}{[Q_e + Q_f + Q_c]}\right] \qquad (17)$$

For the case when Q_c is zero,

$$M_{fg} = 100\left[\frac{0.01\ M_eQ_e + 1.95\ Q_f + 0.0015\ H_e}{(Q_e + Q_f)}\right] \qquad (18)$$

For the case when Q_c is zero, substituting Equations 6 and 18 into Equation 14 and simplifying leads to the following expression:

$$Q_f = \left[\frac{Q_e[(1+0.002M_e+0.0003h_e)Cp_{air}(T_c-T_r)-(1+0.002M_e)Cp_{air}(T_{he}-T_r)-h_e]}{h_f - 1.4\ Cp_{air}(T_c-T_r)}\right] \qquad (19)$$

For the case when Q_c is greater than zero, substituting Equations 6, and 17 into Equation 16, and simplifying leads to the following expression:

$$Q_f = Q_e\left[\frac{[A]Cp_{air}\ (T_c-T_r) - (1+0.002\ M_e)\ Cp_{air}\ (T_{he}-T_r) - h_e]}{h_f - [1.4 + 9.4(1+0.01ex)(1+0.002M_c)]\ Cp_{air}\ (T_c-T_r)}\right] \qquad (20)$$

where:

$$[A] = [(1+0.002\ M_e) + 0.0003\ h_e] + [0.01h_e\ (1+0.01ex) - 0.0476\ O_2]$$

Application of Equations:

Supplementary fuel requirements (Q_f):

Determine the values for the variables in Equations 14, 16, 19, and 20 as follows:

Q_e, O_2, M_e, h_e Input data

Cp_e, Cp_{fg}	Use Equation 5 and Table B.4-1 if composition data are available. If approximate values are sufficient, use Equations 6 and 9 with Table B.4-1 when the values M_e and M_{fg} are known.
Cp_{air}	Use Table B.4-1.
T_c	Obtain value from Table 4.1-1 or from permit applicant.
T_r	70^oF.
T_{he}	Calculate T_{he} using the following expression if the value for T_{he} is not specified. $T_{he} = (HR/100)\ T_c + [1-(HR/100)]\ T_e$ where HR is the heat recovery in the exchanger, percent. Assume a value of 50 percent for HR if no other information is available (see Appendix B.5 for details of the heat exchanger design).
ex	Use a value of 18 percent if no other information is available.
h_f	Assume a value of 882 Btu/scf if no other information is available.
M_c	Use a value of 2 percent (air at 70^oF and 80 percent humidity) if no other information is available.

For emission streams that are dilute mixtures of VOC and air, use Equation 14 or 19; for others, use Equation 16 or 20. Equations 19 and 20 are based on Equations 14 and 16 with the values for Cp_e and Cp_{fg} approximated from Cp_{air} and corrected for presence of moisture. Note that if a negative value is obtained from Equation 16 or 20, this indicates that $Q_c = 0$.

As preheat temperature (T_{he}) and/or heat content (h_e) of the emission stream increase, Equations 14 and 16 or 19 and 20 predict that no supplementary fuel is needed to attain the desired combustion temperature in the incinerator. However, a certain amount of supplemental fuel is always required to ensure that the emission stream is raised above its ignition temperature so that its heat content will be released. The heat supplied by the supplementary fuel fuel is $H_f = Q_f h_f$. In this manual, it is assumed that a minimum H_f of 5 Btu/min is required per scfm of emission stream.[3] In other words, if H_f is less than 5 Btu/min, calculate $Q_{f,min}$ as follows:

$$Q_{f,min} = 5/h_f \qquad (21)$$

Combustion air requirement (Q_c):

For emission streams that are dilute mixtures of VOC and air, $Q_c = 0$. For others, use Equation 12.

Flue gas flow rate (Q_{fg}):

For emission streams that are dilute mixtures of VOC and air, use Equation 13. In other cases, use Equation 15.

References:

1. Hougen, O. A., K. M. Watson, and R. A. Ragatz. Chemical Process Principles. Part I: Material and Energy Balances. Asia Publishing House, Bombay. 1962.

2. Steam/Its Generation and Use. The Babcock and Wilcox Company. New York, NY 1975.

3. U. S. EPA. Organic Chemical Manufacturing. Volume 4: Combustion Control Devices. EPA-450/3-80-026. December 1980.

APPENDIX B.5

HEAT EXCHANGER DESIGN[1,2,3]

This appendix discusses a simple design procedure to estimate the heat transfer area required for recovering a portion of the sensible heat from the incinerator flue gases to preheat the emission stream entering the incinerator. It also describes how the variables in the equations are determined and the application of the equations.

Design Procedure:

Based on the overall heat transfer rate in the exchanger, the expression for the heat exchanger surface area (A) is as follows:

$$A = 60\ H_{he}/U\,\Delta T_{LM} \qquad (1)$$

where:

A = heat exchanger surface area, ft^2

H_{he} = heat transfer rate in the exchanger, Btu/min

U = overall heat transfer coefficient, $Btu/hr\text{-}ft^2\text{-}^oF$

ΔT_{LM} = logarithmic mean temperature difference, ^oF

The logarithmic mean temperature difference is expressed as:

$$\Delta T_{LM} = [(T_c - T_{he}) - (T_{hc} - T_e)]/\ln[(T_c - T_{he})/(T_{hc} - T_e)] \qquad (2)$$

where:

T_c = temperature of flue gas entering the heat exchanger, ^oF

T_{he} = temperature of emission stream leaving the heat exhanger, ^oF

T_{hc} = temperature of flue gas leaving the heat exchanger, ^oF

T_e = temperature of emission stream entering the heat exchanger, ^oF

For a recuperative heat exchanger where the heat transfer takes place between two gas streams, the overall heat transfer coefficient (U) ranges from 2 to 8 $Btu/hr\text{-}ft^2\text{-}^oF$, generally depending on the heat exchanger configuration and properties of the gas streams. For accurate heat exchanger design, the overall heat transfer coefficient is calculated using data on heat transfer coefficients, fouling factors, etc.

In Equation 1, the heat transfer rate in the exchanger (H_{he}) is equal to the sensible heat gained by the emission stream and can be expressed as follows:

$$H_{he} = Q_e Cp_e \, (T_{he} - T_e) \qquad (3)$$

where:

Q_e = emission stream flow rate, scfm
Cp_e = average specific heat of the emission stream, Btu/scf-^{o}F

Substituting Equation 3 in 1 yields the following general expression for the heat exchanger surface area:

$$A = [60 \, Q_e \, Cp_e \, (T_{he} - T_e)]/U \Delta T_{LM} \qquad (4)$$

Cp_e can be approximated as $[(1 + 0.002 \, M_e) \times Cp_{air}]$ with M_e denoting the moisture content of the emission stream (volume, percent) and Cp_{air} denoting the average specific heat of air for the appropriate temperature range (see Appendix B.4 for details). Thus,

$$A = 60 \, Q_e \, (1 + 0.002 \, M_e) Cp_{air} (T_{he} - T_e)/U \Delta T_{LM} \qquad (5)$$

The value of the preheat temperature (T_{he}) of the emission stream is determined by the heat recovery (HR) assumed in the heat exchanger. The heat recovery is expressed as:

$$HR = 100 \, [(T_{he} - T_e)/(T_c - T_e)] \qquad (6)$$

where HR represents the percentage of the total heat available for recovery. Solving Equation (6) for T_{he} yields the following expression:

$$T_{he} = (HR/100)\ T_c + [1 - (HR/100)]\ T_e \qquad (7)$$

In general, the emission stream temperature determines the maximum heat recovery that is possible, and cost considerations affect the optimum heat recovery. Preheating the emission stream to the combustion temperature by heat exchange is not possible due to temperature limitaticns related to the ductwork material. Also, raising the emission stream temperature to the combustion temperature is not advisable since oxidation may occur in the ductwork prior to the stream entering the incinerator.

Generally, the value for ΔT_{LM} is calculated from Equation (2). If (T_c-T_{he}) and $(T_{hc}-T_e)$ are nearly equal, then ΔT_{LM} can be approximated from the arithmetic average of (T_c-T_{he}) and $(T_{hc}-T_e)$ as follows:

$$\Delta T_{LM} = [(T_c-T_{he}) + (T_{hc}-T_e)]/2 \qquad (8)$$

If the value for T_{hc} is not available, it can be determined from the heat exchange between the emission stream and flue gas:

$$Q_e[Cp_e(T_{he}-T_r) - Cp_e(T_e-T_r)] = Q_{fg}[Cp_{fg}\ (T_c-T_r) - Cp_{fg}\ (T_{hc}-T_r)] \qquad (9)$$

where:

Q_{fg} = flue gas flow rate, scfm
Cp_{fg} = average specific heat of the flue gas, Btu/scf-^{o}F

However, this will involve a trial and error procedure since Cp_{fg} for the interval (T_r-T_{hc}) depends on T_{hc}. Cp_{fg} can be approximated as $[(1 + 0.002M_{fg}) \times Cp_{air}]$ with M_{fg} denoting the moisture content of the flue gas (volume, percent) and Cp_{air} denoting the average specific heat of air for the apprpriate temperature interval.

For dilute emission streams that do not require additional combustion air, $Q_e\ Cp_e \cong Q_{fg}Cp_{fg}$ and Equation 9 can be simplified as follows:

$$T_{hc} = T_c - (T_{he} - T_e) \qquad (10)$$

The expression for ΔT_{LM} reduces to:

$$\Delta T_{LM} = T_c - T_{he} \qquad (11)$$

Determination of the Variables and the Application of the Equations

Determine the values of the variables in Equations 5, 7, 8, 9, and 11 as follows:

Q_e, T_e, M_e	Input data
T_{he}	Calculate using Equation 7 if a value for T_{he} is not specified. Assume a value of 50 percent for heat recovery (HR) if no other information is available.
Cp_{air}	See Table B.4-1.
U	Use a value of 4 Btu/hr-ft^2-^oF unless the applicant/inquirer has provided a value.
ΔT_{LM}	A. For dilute emission streams requiring no additional combustion air: Use Equation 11; obtain the value for T_c from Table 4.1-1 or from permit applicant. B. For emissions streams that are not dilute and require additional combustion air: Use Equation 8 if $(T_c - T_{he})$ and $(T_{hc} - T_e)$ are nearly equal; otherwise use Equation 2. The value for T_{hc} in these equations is determined using Equation 9. Refer to Appendix B.4 for calculating the value for Q_{fg} and M_{fg}.

References:

1. U. S. EPA. Afterburner Systems Study. EPA-R2-72-062. August 1972.
2. U. S. EPA. Organic Chemical Manufacturing. Volume 4: Combustion Control Devices. EPA-450/3-80-026. December 1980.
3. McCabe, W. L and J. C. Smith. Unit Operations of Chemical Engineering. Second edition. McGraw-Hill Book Company, Inc. and Kogakusha Company, Ltd. Tokyo. 1957.

APPENDIX B.6

CATALYTIC INCINERATOR CALCULATIONS

This appendix describes the derivation of the equations used in calculating supplementary fuel requirements (Q_f), additional combustion air requirements (Q_c), combined gas stream entering the catalyst bed (Q_{com}), and resulting flue gas (Q_{fg}). It also describes how the various parameters in the equations are to be determined and discusses the application of the equations. Standard conditions assumed are: 70^oF and 1 atm.

Derivation:

Supplementary fuel is added to the catalytic incinerator system to provide the heat necessary to bring the emission stream (and the combustion air, if applicable) up to the required catalytic oxidation temperature (T_{ci}) for the desired level of destruction efficiency. For a given T_{ci}, the quantity of heat needed (H_c) is provided by: (a) the heat generated from the combustion of supplementary fuel (H_f), (b) the sensible heat contained in the emission stream as it enters the catalytic incinerator system (H_s), and (c) the sensible heat gained by the emission stream through heat exchange (H_{he}). Thus,

$$H_c = H_f + H_s + H_{he} \qquad (1)$$

A. Each term in Equation (1) is expanded as follows (see Appendix B.4 for details):

$$H_f = Q_f \; h_f \qquad (2)$$

In this manual, the supplementary fuel is assumed as natural gas.

$$H_s = Q_e \; Cp_e \; (T_e - T_r) \qquad (3)$$

$$H_{he} = Q_e \; Cp_e \; (T_{he} - T_r) \qquad (4)$$

$$H_c = Q_{com} \; Cp_{com} \; (T_{ci} - T_r) \qquad (5)$$

where:

Q_f = supplementary fuel (natural gas) flow rate, scfm

h_f = heating value of supplementary fuel (natural gas), Btu/scf

Q_e = emission stream flow rate, scfm

Cp_e = average specific heat of the emission stream (based on the interval $T_r - T_e$ or $T_r - T_{he}$), Btu/scf-^oF

Q_{com} = flow rate of the combined gas stream (emission stream + supplementary fuel combustion products) entering the catalyst bed, scfm

Cp_{com} = average specific of the combined gas stream (based on the interval $T_r - T_{ci}$), Btu/scf-^oF

T_e = emission stream temperature as it leaves the emission source, ^oF

T_r = reference temperature, = 70^oF

T_{he} = temperature of the emission stream exiting the heat exchanger, ^oF

T_{ci} = temperature of the combined gas stream entering the catalyst bed, ^oF

B. The flow rate of combined gas stream (emission stream + supplementary fuel combustion products) entering the catalyst bed is dependent on the emission stream flow rate (Q_e), supplementary fuel (natural gas) flow rate (Q_f), and additional air required for combustion of supplementary fuel and hydrocarbons in the emission stream (Q_c).

$$Q_{com} = Q_e + Q_f + Q_c \qquad (6)$$

The additional combustion air requirement is a function of the emission stream VOC concentration expressed in terms of the heat content variable (h_e), oxygen content (O_2), and the quantity of supplementary fuel. It can be expressed as follows (see Appendix B.4 for details):

$$Q_c = (0.01 h_e Q_e + 9.4 Q_f)(1 + 0.01 ex) - 0.0476\ O_2 Q_e \qquad (7)$$

where ex = excess air, percent. In general, emission streams treated by catalytic incineration are dilute and contain significant quantities of oxygen (typically greater than 16 percent). In such cases, Q_c=0 and Q_{com} then becomes:

$$Q_{com} = Q_e + Q_f \tag{8}$$

Substituting Equations 2, 3, 4, 5, and 8 in 1 and solving for (Q_f/Q_e) yields the following expression:

$$(Q_f/Q_e) = \left[\frac{Cp_{com}(T_{ci}-T_r) - Cp_e(T_{he}-T_r)}{h_f - Cp_{com}(T_{ci}-T_r)}\right] \tag{9}$$

For emission streams that are not dilute and require additional combustion air, the equation for (Q_f/Q_e) becomes:

$$(Q_f/Q_e) = \left[\frac{[1+0.01\ h_e(1+0.01ex)-0.0476O_2]Cp_{com}(T_{ci}-T_r)-Cp_e(T_{he}-T_r)}{h_f-(10.4+0.094ex)Cp_{com}(T_{ci}-T_r)}\right] \tag{10}$$

Simplification of Equations 9 and 10:

The values for Cp_e and Cp_{com} can be evaluated from the specific heats of the individual components in each stream as indicated in Appendix B.4. As an approximation, however, Cp_e and Cp_{com} can be assumed to equal the average specific heat of air containing water vapor over the same temperature range:

$$Cp_e = (1+0.002M_e)Cp_{air} \tag{11}$$

$$Cp_{com} = (1+0.002\ M_{com})Cp_{air} \tag{12}$$

where:

M_e = emission stream moisture content, percent
M_{com} = combined gas stream moisture content, percent

Cp_{air} = average specific heat of air, Btu/scf-^{o}F

The value for M_e is available from input data. The value for M_{com} for dilute emission streams that do not require additional combustion air is given as (see Appendix B.4 for details):

$$M_{com} = 100\left[\frac{(0.01M_eQ_e+1.95Q_f)}{(Q_e+Q_f)}\right] \tag{13}$$

For emission streams that require additional combustion air:

$$M_{com} = 100\left[\frac{(0.01M_eQ_e+1.95Q_f+0.01M_cQ_c)}{(Q_e+Q_f+Q_c)}\right] \tag{14}$$

where:

M_c = combustion air moisture content, percent

Using Equations 11 and 12 with 13 and substituting in Equation 9 leads to the following expression for dilute emission streams where $Q_c = 0$:

$$(Q_f/Q_e) = \left[\frac{(1+0.002M_e)[Cp_{air}(T_{ci}-T_r)-Cp_{air}(T_{he}-T_r)]}{h_f-1.4Cp_{air}(T_{ci}-T_r)}\right] \tag{15}$$

For emission streams that are not dilute and require additional combustion air, the equivalent expression for (Q_f/Q_e) becomes:

$$(Q_f/Q_e) = \left[\frac{(1+0.002M_e)(1+[0.01h_e(1+0.01ex)-0.0476O_2](1+0.002M_c)Cp_{air}(T_{ci}-T_r)-Cp_{air}(T_{he}-T_r))}{h_f-(1.4+9.4(1+0.01ex)(1+0.002M_c)]Cp_{air}(T_{ci}-T_r))}\right] \tag{16}$$

Note that the heat supplied by the supplementary fuel is Q_fh_f, which can be calculated by multiplying (Q_f/Q_e) with Q_e and h_f.

Determination of Variables and Application of Equations:

Supplementary fuel requirements (Q_f):

For emission streams that are dilute mixtures of VOC and air, use Equation 9 or 15; for others, use Equation 10 or 16. Equations 15 and 16 are based on Equations 9 and 10 with the values for Cp_e and Cp_{com} approximated from Cp_{air} and corrected for presence of moisture.

The minimum value for T_{ci} in Equations 9, 10, 15, and 16 is designated as 600^oF in this manual to ensure an adequate initial reaction rate. In practice, the minimum value for T_{ci} will be dependent on the type of VOC present in the emission stream and the catalyst properties. The minimum value for the temperature of the flue gas exiting the catalyst bed (T_{co}) is designated as $1,000^oF$. As illustrated in Table B.6-1 and Figure B.6-1, for a specified destruction efficiency level, the value for T_{co} is dependent on the type of VOC present in the emission stream. The values in the table refer to fresh catalysts; higher temperatures will be required as the catalyst activity declines due to aging and possible poisoning. The destruction efficiency for a given compound may vary depending on whether the compound is part of a mixture or not. It may also vary with the mixture composition as shown in Figures B.6-2 and 3 where compound specific destruction efficiency data for two different VOC mixtures are presented.

To prevent overheating of the catalyst bed, T_{co} should not exceed $1,200^oF$ on a continuous basis. Otherwise, the catalyst's activity may decline, and the catalyst may need to be replaced to maintain satisfactory performance levels.

Before using the equations to determine Q_f, the adequacy of $T_{ci} = 600^oF$ should be checked to determine if the overall reaction rate for a given destruction efficiency will result in a temperature level of at least $1,000^oF$ at the catalyst bed outlet. Use the following equation to check if $T_{co} = 1,000^oF$.

$$T_{co} = 600 + 50\ h_e \qquad (17)$$

where the term "$50h_e$" denotes the temperature rise associated with the combustion of the hydrocarbons in the emission stream across the catalyst bed.

TABLE B.6-1. TEMPERATURES FOR CATALYTIC OXIDATION[a]

Component	Catalytic Ignition Temperatures for 90 Percent Destruction Efficiency,[b] T_{co} (°F)
Hydrogen	68
Carbon Monoxide	300-390
Methane	840-930
n-Heptane	480-570
Benzene	480-570
Toluene	480-570
Xylene	480-570
Methyl isobutyl ketone	570-660
Methyl ethyl ketone	570-660
Mesityl oxide	480-570
Ethyl acetate	750-840
Dimethyl formamide	660-750
Pyridine	750-840
Thiophene	750-840
Chlorobutane	840-930

[a] Source: Reference 1.

[b] The values refer to fresh platinum catalysts supported on Al_2O_3.

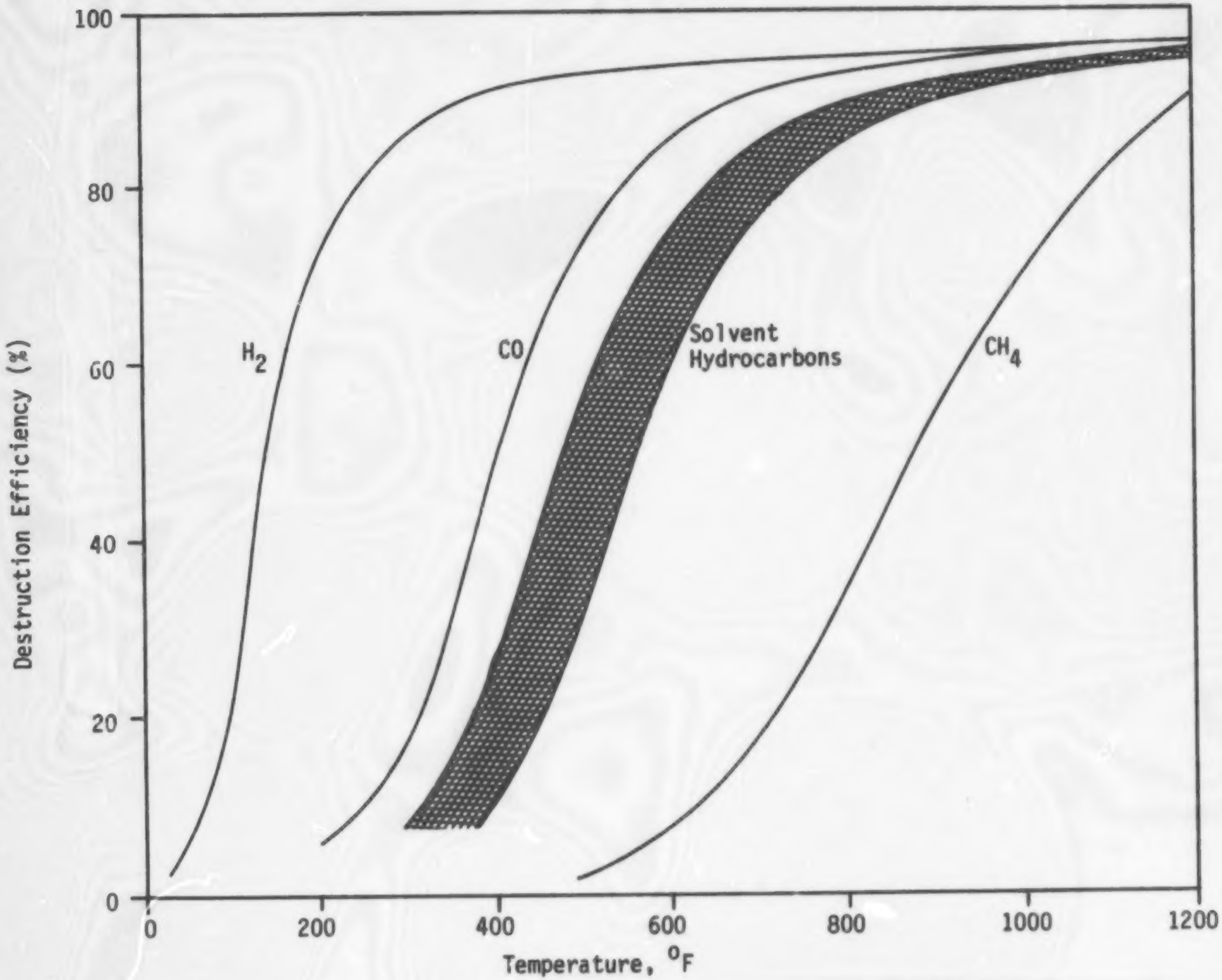

Figure B.6-1. Effect of average catalyst bed temperature on destruction efficiency for various species oxidized over Platinum/Al_2O_3 catalysts.
(Source: Reference 1)

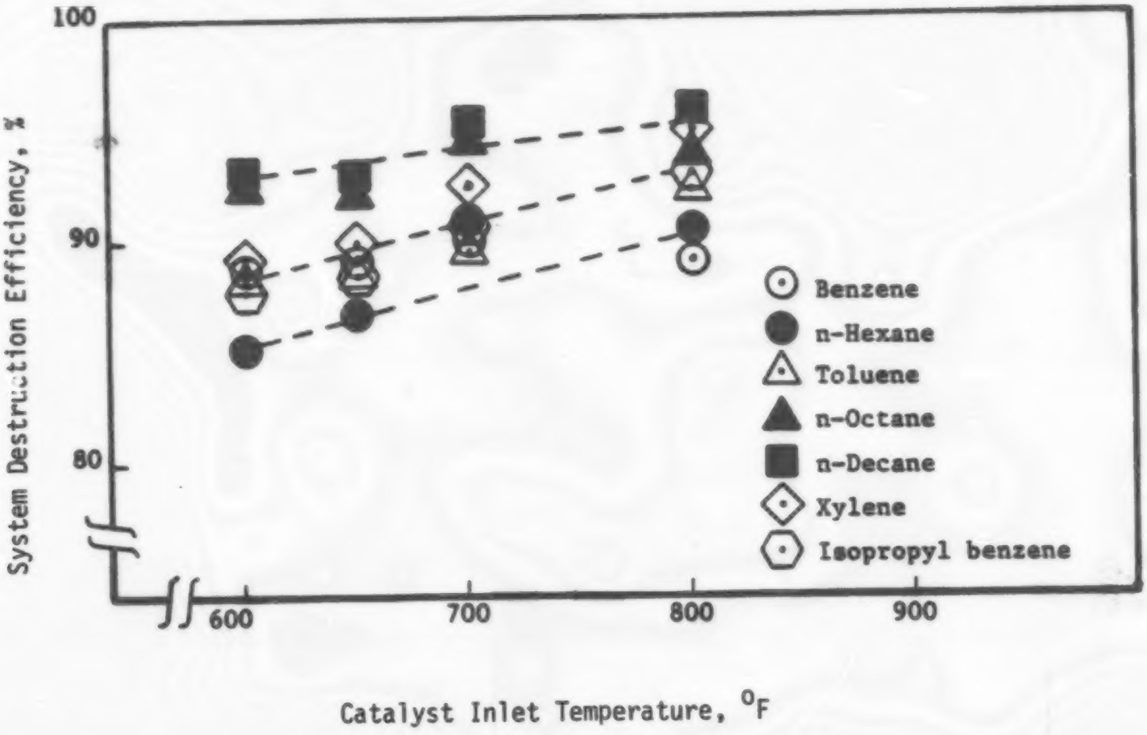

Figure B.6-2. Component system destruction vs. temperature. (Source: Reference 2)

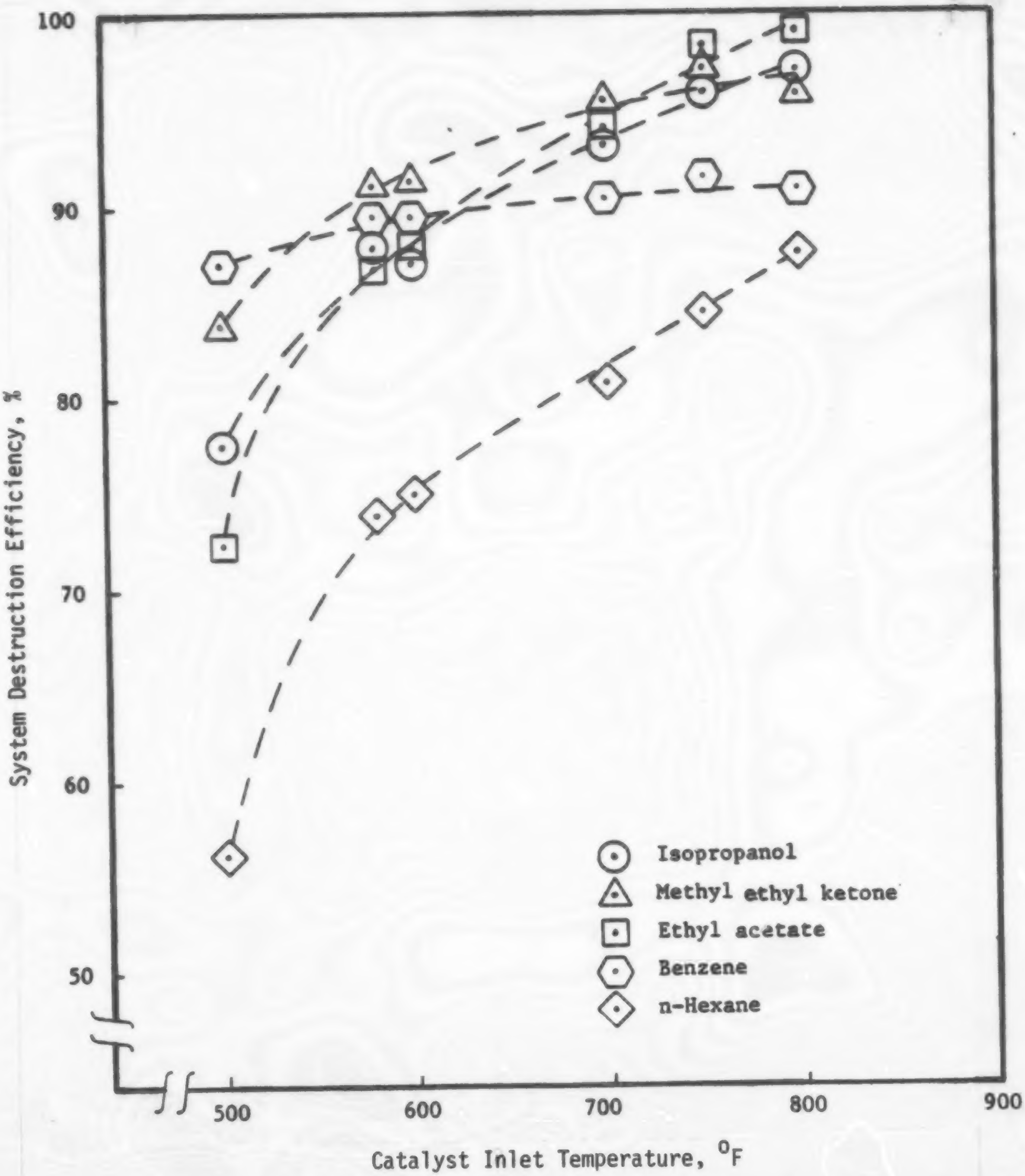

Figure B.6-3. Component system destruction vs. temperature. (Source: Reference 2)

In other words, if the emission stream has a heat content of 1 Btu/scf, this will result in a 50^oF temperature rise. This expression assumes that the heat content of the emission stream is the same as that of the combined gas stream. The difference is negligible for emission streams that are dilute mixtures of air and VOC. For emission streams that require additional combustion air, the change in heat content should be taken into consideration. If $T_{ci} = 600^oF$ results in T_{co} that is less than $1,000^oF$, use the following equation to determine an appropriate value for T_{ci}:

$$T_{ci} = 1,000 - 50\ h_e \tag{18}$$

Use the value obtained from this equation for T_{ci} in the equations for Q_f/Q_e.

Determine the values for the parameters in Equations 9, 10, 15, and 16 as follows:

Q_e, O_2, M_e, h_e	Input data
Cp_e, Cp_{com}	If composition data are available, see Appendix B.4. If approximate values are sufficient, use Equations 11 and 12 with Table B.4-1 in Appendix B.4 when the values M_e and M_{com} are known.
Cp_{air}	Use Table B.4-1 in Appendix B.4.
T_{ci}	Check if 600^oF is satisfactory using Equation 17. If it is not, use Equation 18 to determine an appropriate value. In a permit evaluation case, obtain value from applicant.

T_r	70^oF
T_{he}	Calculate T_{he} using the following expression if the value for T_{he} is not specified: $T_{he} = (HR/100)T_{co}+[1-(HR/100)]T_e$ where HR is the heat recovery in the exchanger, percent. Assume a value of 50 percent for HR if no other information is available (see Appendix B.5 for details of heat exchanger design).
ex	Use a value of 18 percent if no other information is available (this is equivalent to approximately 3 percent O_2 in the flue gas).
h_f	Assume a net heating value of 882 Btu/scf (for natural gas) if no other information is available.
M_c	Use a value of 2 percent (air at 70^oF and 80% humidity) if no other information is available.

Combustion air requirement (Q_c):

For emission streams that are dilute mixtures of VOC and air, Q_c=0. For others, use Equation 7.

Flow rate of combined gas stream (Q_{com}):

For emission streams that are dilute mixtures of VOC and air, use Equation 8. In other cases, use Equation 6.

Flow rate of flue gas (Q_{fg}):

Assume that the change in volume due to the combustion of VOC in the combined gas stream at standard conditions across the catalyst bed is small; thus, Q_{fg} can be approximated as Q_{com}.

References:

1. U. S. EPA. Afterburner Systems Study. EPA-R2-72-062. August 1972.

2. U. S. EPA. Parametric Evaluation of VOC/HAP Destruction Via Catalytic Incineration. EPA-600/2-85-041. April 1985.

APPENDIX B.7
FLARE CALCULATIONS

This appendix describes the details of the calculations described in Section 4.3.

Background[1]

Based on studies conducted by EPA, a destruction efficiency of 98 percent can be achieved in flares for waste gases with heat contents greater than or equal to 300 Btu/scf. In this manual, it is assumed that if the heat content of the emission stream is below 300 Btu/scf, then natural gas as the auxiliary fuel will be added to the emission stream to bring its heat content to 300 Btu/scf. The exit velocities with which this level of destruction efficiency can be obtained are expressed as follows: If the heat content of the flare gas (emission stream or emission stream + natural gas, if auxiliary fuel is required) is in the range 300-1,000 Btu/scf (inclusive), the maximum exit velocity that can be used is obtained from the following equation:

$$U_{max} = 3.28[10^{(0.00118h_{flg} + 0.908)}] \qquad (1)$$

where:

U_{max} = maximum flare gas exit velocity, ft/sec
h_{flg} = flare gas heat content, Btu/scf

If the heat content of the flare gas exceeds 1,000 Btu/scf, then the maximum exit velocity that can be used is 400 ft/sec (the value corresponding to Equation (1) evaluated at h_{flg} = 1,000 Btu/scf). At very low flare gas flow rates, flame instability may occur. To prevent this, the minimum flare gas exit velocity is assumed to be 0.03 ft/sec.[2]

Supplementary Fuel Requirements:

Assuming natural gas with a heating value of 882 Btu/scf as the auxiliary fuel (see Appendix B.4), the quantity of natural gas required to raise the heat content of the emission stream to 300 Btu/scf can be determined from the following energy balance:

$$Q_f h_f + Q_e h_e = (Q_f + Q_e) h_{flg} \quad (2)$$

where

Q_f = natural gas flowrate, scfm
h_f = natural gas heating value, = 882 Btu/scf
Q_e = emission stream flowrate, scfm
h_e = emission stream heat content, Btu/scf
h_{flg} = flare gas heat content, = 300 Btu/scf

Solving for Q_f and substituting for h_f and h_{flg} yields the following equation:

$$Q_f = [(300-h_e)\ Q_e]/582 \quad (3)$$

Flare Gas Flow Rate, Temperature, and Mean Molecular Weight:

Flare gas flow rate is equal to the emission stream flow rate if no auxiliary fuel is required. Otherwise, it can be expressed as follows:

$$Q_{flg} = Q_e + Q_f \quad (4)$$

where:

Q_{flg} = flare gas flow rate, scfm.

Flare gas mean molecular weight is the same as that of the emission stream if no natural gas is added as auxiliary fuel. If natural gas is added, then this variable has to be calculated using a mass balance expression:

$$Q_f MW_f + Q_e MW_e = Q_{flg} MW_{flg} \quad (5)$$

where:

MW_f = molecular weight of natural gas, = 16.7 lb/lb-mole (see Appendices B.1 and B.4)
MW_e = molecular weight of emission stream, lb/lb-mole
MW_{flg} = molecular weight of flare gas, lb/lb-mole

$$MW_{flg} = (Q_f \times 16.7 + Q_e\ MW_e)/\ Q_{flg} \qquad (6)$$

Temperature of the flare gas after the emission stream is mixed with natural gas can be calculated from an energy balance (based on 70°F as the reference temperature):

$$[Q_f MW_f \underline{C}p_f(T_f-70)/387]+[Q_e MW_e \underline{C}p_e(T_e-70/387] = [Q_{flg} MW_{flg} \underline{C}p_{flg}(T_{flg}-70)/387] \quad (7)$$

where:

$\underline{C}p_f$ = average specific heat of natural gas, Btu/lb-°F
$\underline{C}p_e$ = average specific heat of emission stream, Btu/lb-°F
$\underline{C}p_{flg}$ = average specific heat of flare gas, Btu/lb-°F

Assuming natural gas is available at 70°F and that $\underline{C}p_e$ and $\underline{C}p_{flg}$ are approximately the same, Equation 7 can be simplified and solved for T_{flg}:

$$T_{flg} = [Q_e MW_e(T_e-70)/Q_{flg} MW_{flg}] + 70 \qquad (8)$$

Steam Requirements:

The steam requirement, Q_s, will be based on a ratio of 0.4 lb steam/lb flare gas in this manual. The following equation can be used to calculate Q_s:

$$Q_s = 0.4 \times Q_{flg}\ (1/387)(MW_{flg}) \qquad (9)$$

where:

Q_s = steam requirement, lb/min

The factor "387" is the volume (scf) occupied by 1 lb-mole of ideal gas at 70°F and 1 atm. Simplifying:

$$Q_s = 1.03 \times 10^{-3}\ (Q_{flg})(MW_{flg}) \qquad (10)$$

References

1. Federal Register. Volume 50. April 16, 1985. pp. 1494-14945

2. U. S. EPA. Organic Chemical Manufacturing Volume 4: Combustion Control Devices. EPA-450/2-80-026. December 1980.

APPENDIX B.8
CARBON ADSORPTION DATA

TABLE B.8-1. REPORTED OPERATING CAPACITIES FOR SELECTED ORGANIC COMPOUNDS

Compound	Average Inlet Concentration (ppmv)	Adsorption Capacity[b] (lb VOC/100 lb carbon)
Acetone	1,000	8
Benzene	10	6
n-Butyl acetate	150	8
n-Butyl alcohol	100	8
Carbon tetrachloride	10	10
Cyclohexane	300	6
Ethyl acetate	400	8
Ethyl alcohol	1,000	8
Heptane	500	6
Hexane	500	6
Isobutyl alcohol	100	8
Isopropyl acetate	250	8
Isopropyl alcohol	400	8
Methyl acetate	200	7
Methyl alcohol	200	7
Methylene chloride	500	10
Methyl ethyl ketone	200	8
Methyl isobutyl ketone	100	7
Perchloroethylene	100	20
Toluene	200	7
Trichlorethylene	100	15
Trichlorotrifluoroethane	1,000	8
Xylene	100	10

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[a] Source: Reference 1.

[b] Adsorption capacities are based on 200 scfm of solvent-laden air at 100°F (per hour).

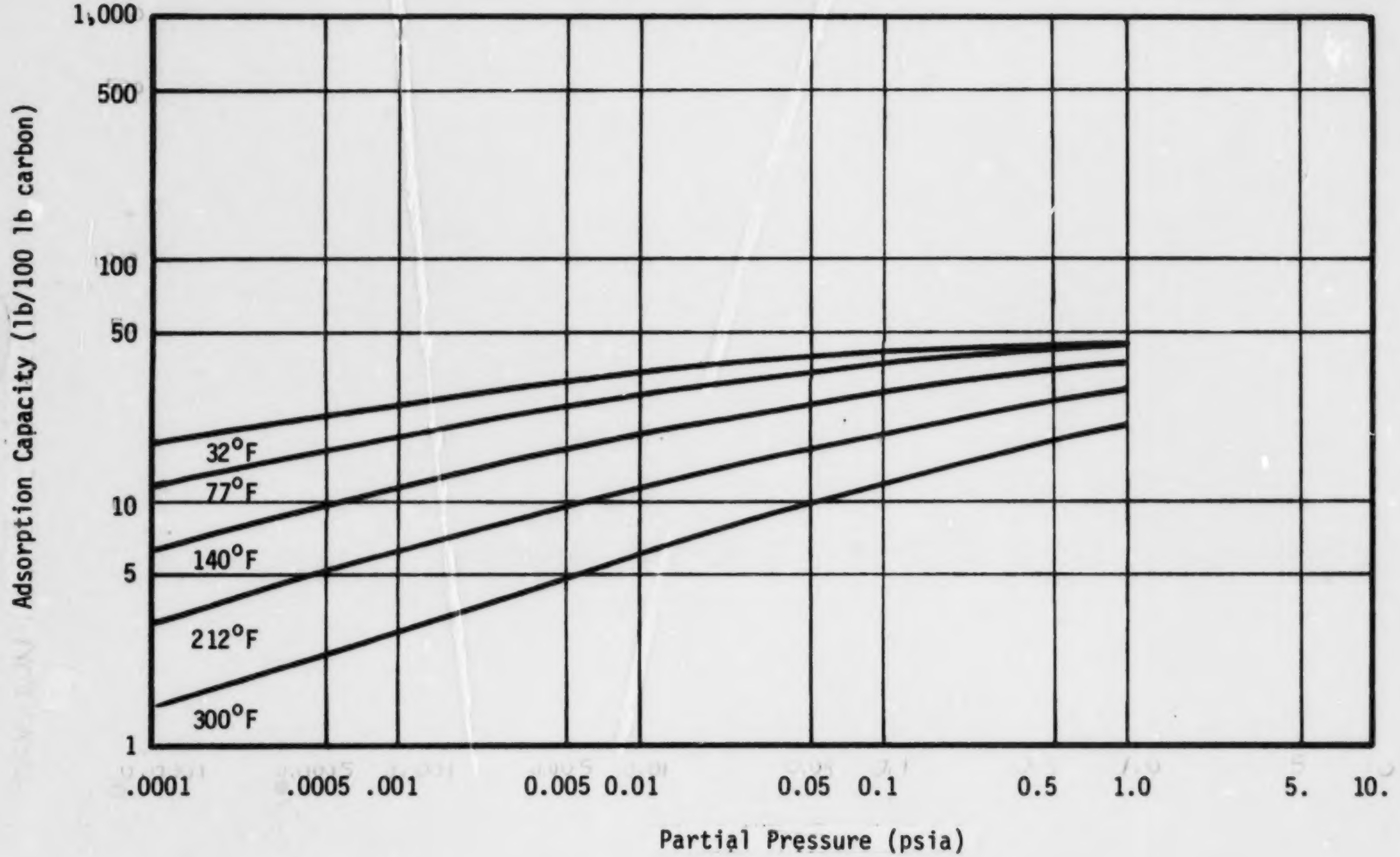

Figure B.8-1. Adsorption isotherm for benzene on BPL activated carbon.
(Source: Reference 2)

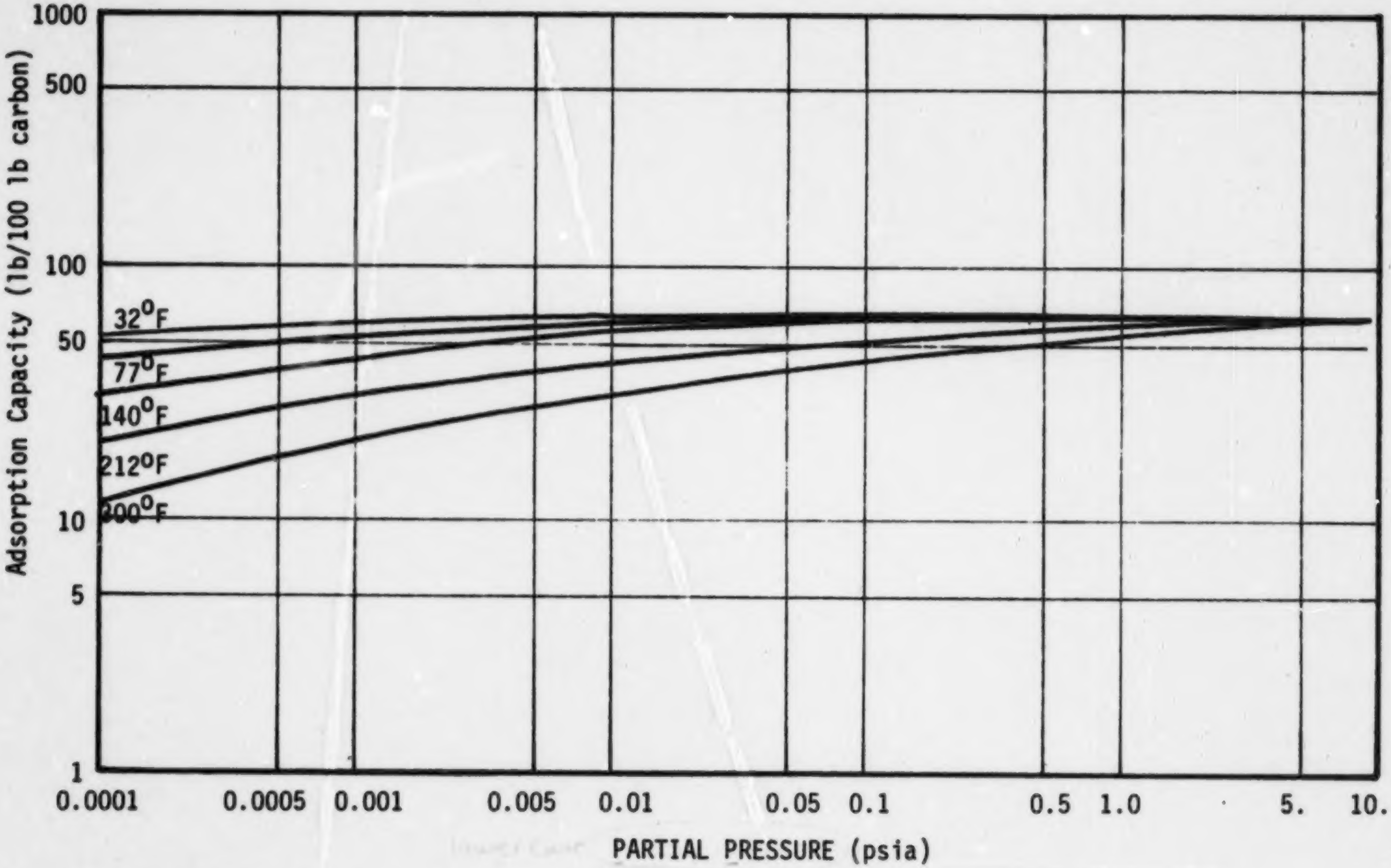

Figure B.8-2. Adsorption isotherm for dichlorobenzene on BPL activated carbon.
(Source: Reference 2)

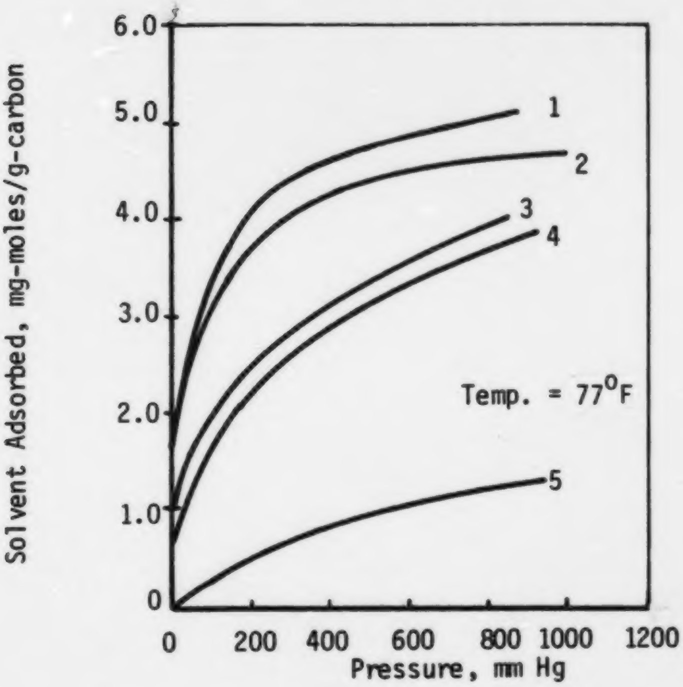

Figure B.8-3. Adsorption isotherms for organic compounds. (Source: Reference 3)

Component Key:

1 - Propylene
2 - Propane
3 - Ethane
4 - Ethylene
5 - Methane

Logarithmic Mean Temperature Difference

The expression for the logarithmic mean temperature difference is as follows:

$$\Delta T_{LM} = \left[\frac{(T_{sti} - T_{wo}) - (T_{sto} - T_{wi})}{\ln[(T_{sti} - T_{wo})/(T_{sto} - T_{wi})]}\right]$$

where:

T_{sti} = steam inlet temperature, ^{o}F
T_{sto} = condensed steam outlet temperature, ^{o}F
T_{wo} = cooling water outlet temperature, ^{o}F
T_{wi} = cooling water inlet temperature, ^{o}F

References

1. Manzone, R. R. and D. W. Oakes. Profitably Recycling Solvents from Process Systems. Pollution Engineering 5(10):23-24. 1973.

2. Calgon Corporation, Pittsburgh, PA. In-house data.

3. Tomany, J. P. Air Pollution: The Emissions, The Regulations, and the Controls. American Elsevier Publishing Company, Inc. New York-London-Amsterdam. pp. 272-302.

APPENDIX B.9
ABSORPTION CALCULATIONS

Calculation of N_{OG}:

The height of a packed column is calculated by determining the required number of theoretical separation units and multiplying this number by the packing height, which gives a performance equal to one separation unit. In continuous contact countercurrent operations, the theoretical separation unit is called the transfer unit. To express the ease (low number of transfer units) or difficulty of the transfer under the conditions of operation with respect to system equilibrium, the system is evaluated as to the number of transfer units, N_{OG} (based on gas phase) or N_{OL} (based on liquid phase).

In actual gas absorption design practice, N_{OG} is obtained experimentally or calculated using several different methods. When dilute solutions are involved (i.e., Henry's Law applies and the equilibrium and operating lines are straight), N_{OG} is given by:[1]

$$N_{OG} = \ln \{[(\bar{y}_1-m\bar{x}_2)/(\bar{y}_2-m\bar{x}_2)][1-(1/AF)] + (1/AF)\}/[1-(1/AF)] \qquad (1)$$

where:

AF = $L_{mol}/G_{mol}m$ = absorption factor

G_{mol} = gas stream (emission stream) flow rate, lb-mole/hr

L_{mol} = liquid stream (solvent) flow rate, lb-mole/hr

$\bar{y}_1$ = mole fraction of pollutant in emission stream entering the absorber

$\bar{y}_2$ = mole fraction of pollutant in emission stream exiting the absorber

$\bar{x}_2$ = mole fraction of pollutant in solvent entering the absorber

m = slope of the equilibrium curve

In cases where $\bar{x}_2 = 0$ (i.e., fresh solvent is free of pollutant), the expression simplifies to:

$$N_{OG} = \ln \{(\bar{y}_1/\bar{y}_2)[1 - (1/AF)] + (1/AF)\}/[1 - (1/AF)] \qquad (2)$$

Schmidt Number (Sc):

In calculating height of a transfer unit, H_G (based on gas phase) or H_L (based on liquid phase), the correlations used employ a dimensionless group termed the Schmidt number. For a given compound in a gas stream, for example, Sc_G is defined as:

$$Sc_G = \mu_G / \rho_G D_G \qquad (3)$$

where:

μ_G = viscosity of gas, lb/ft-hr
ρ_G = density of gas stream, lb/ft^3
D_G = diffusivity of a given vapor component in a gaseous stream, ft^2/hr

Similarly, Sc_L for the liquid phase is defined as:

$$Sc_L = \mu_L / \rho_L D_L \qquad (4)$$

where the viscosity, density, and the diffusivity refer to the liquid phase.

To calculate Sc_G or Sc_L, use References 2 or 3 for viscosity, density and diffusivity data.

Calculation of Emission Stream (Gas) Density (ρ_G):

Assuming ideal gas conditions, the density of a gas stream at a given temperature is given by:

$$\rho_G = P_t \times MW_e/[R(T_e + 460)] \qquad (5)$$

where:

ρ_G = emission stream density, lb/ft^3
P_t = total pressure in the system, atmosphere
MW_e = molecular weight of emission stream, lb/lb-mole
R = gas constant = 0.73 lb-mole $^oR/ft^3$-atm
T_e = emission stream temperature, ^oF

Calculation of Column Weight (Wt_{column}):

For costing purposes, column weight is computed from column height, diameter, and thickness as follows:[4]

$$Wt_{column} = \pi D_{column}[Ht_{total} + (0.8116 \times D_{column})]Th_{column} \times \rho_c \qquad (6)$$

where:

Wt_{column} = column wt, lb
D_{column} = column diameter, ft
Ht_{total} = total column height, ft
Th_{column} = coulmn thickness, ft
ρ_c = density of carbon steel plate, lb/ft^3

The variable Th_{column} is a complex function of several factors including internal pressure, wind loading, and corrosion allowance. At pressures close to atmospheric, Th_{column} of 1/4 to 1/2 inches are adequate. At these thicknesses, corresponding values for ($Th_{column} \times \rho_c$) are 10.2 to 20.4 lb/ft^2. Assuming ($Th_{column} \times \rho_c$) as 15.3 lb/ft^2 (midpoint of the range 10.2 to 20.4), Equation 6 can be simplified as:

$$Wt_{column} = 3.14 \times D_{column}[Ht_{total} + 0.8116 \times D_{column})]15.3 \qquad (7)$$

$$Wt_{column} = (48 \times D_{column} \times Ht_{total}) + 39\ (D_{column})^2 \qquad (8)$$

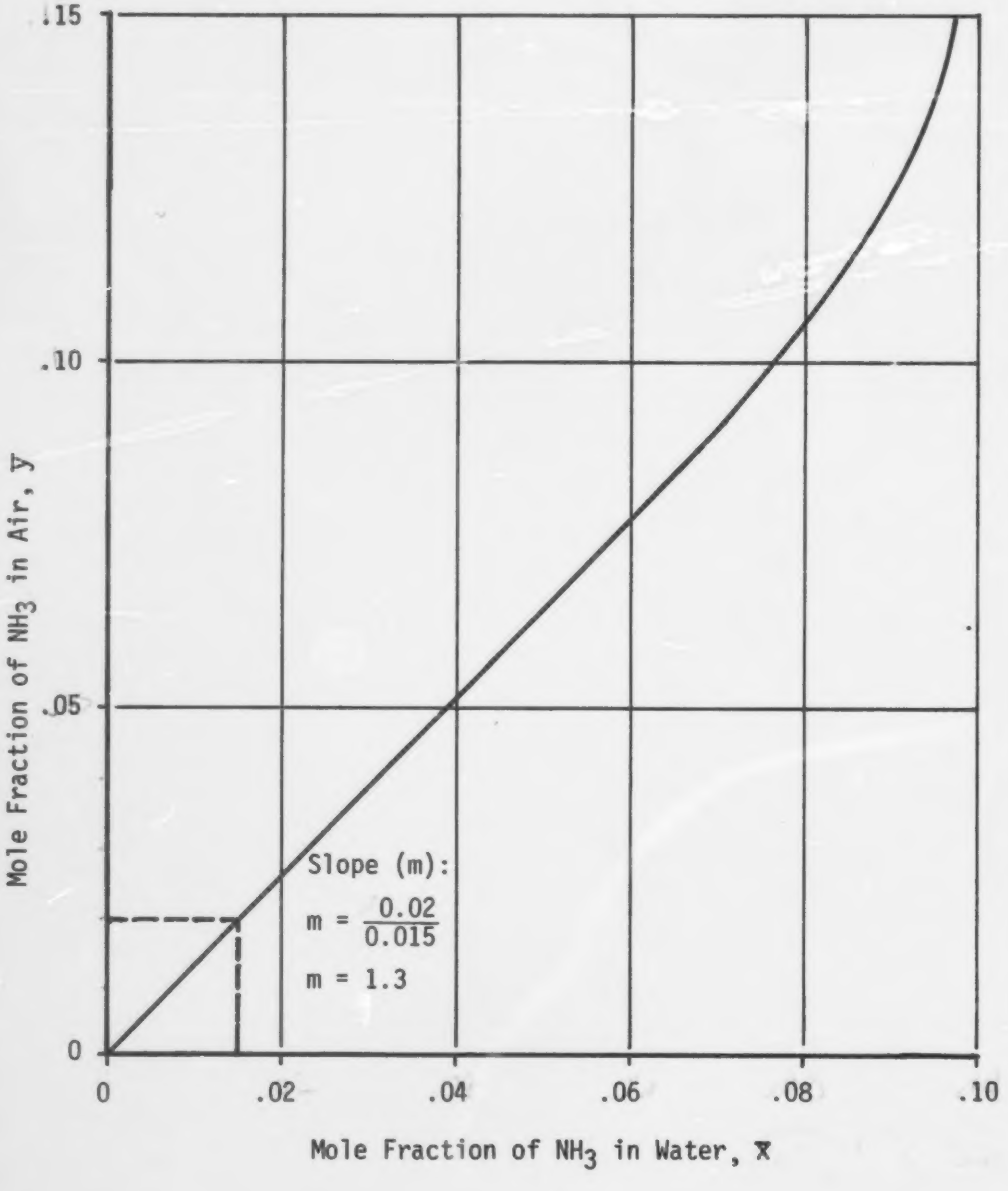

Figure B.9-1. Ammonia (NH_3)-water-air equilibrium at 86°F and 1 ATM. (Source: Reference 1)

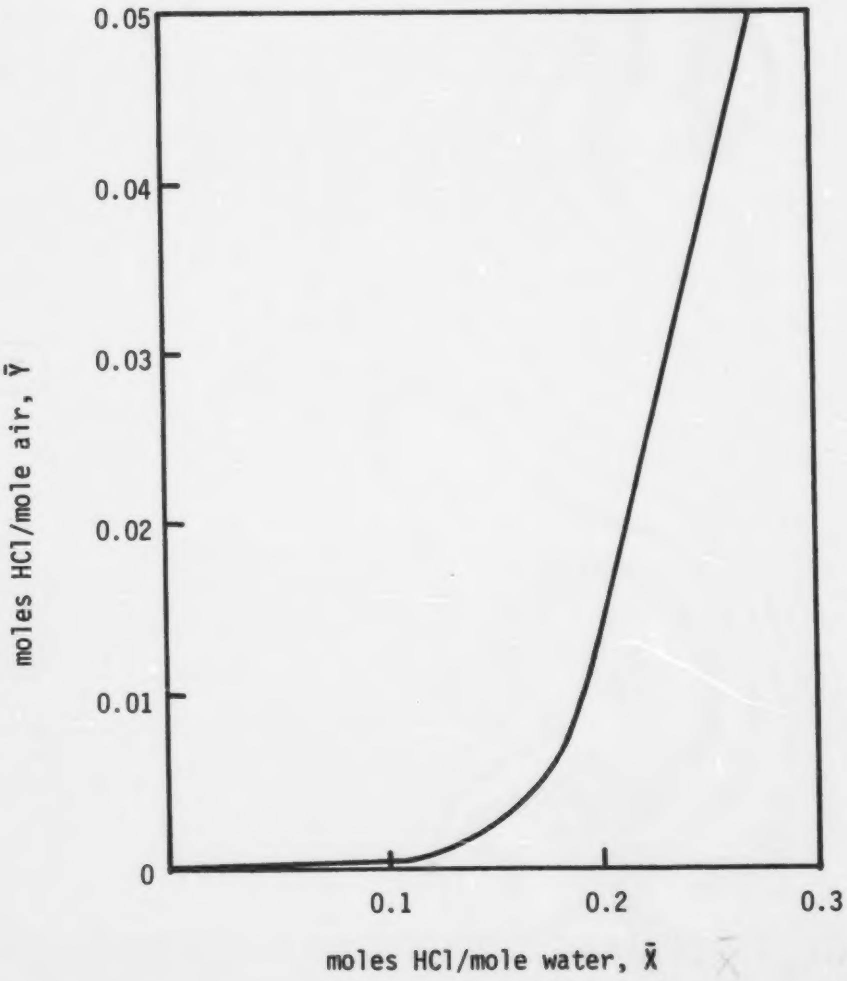

Figure B.9-2. Equilibrium curve for hydrogen chloride (HCl)-air-water system at 68°F. (Source: Reference 1)

Note: The slope of the equilibrium curve can be determined from the following expression:

$$\frac{\bar{Y}}{(1 + \bar{Y})} = \frac{\bar{X}}{(1 + \bar{X})}$$

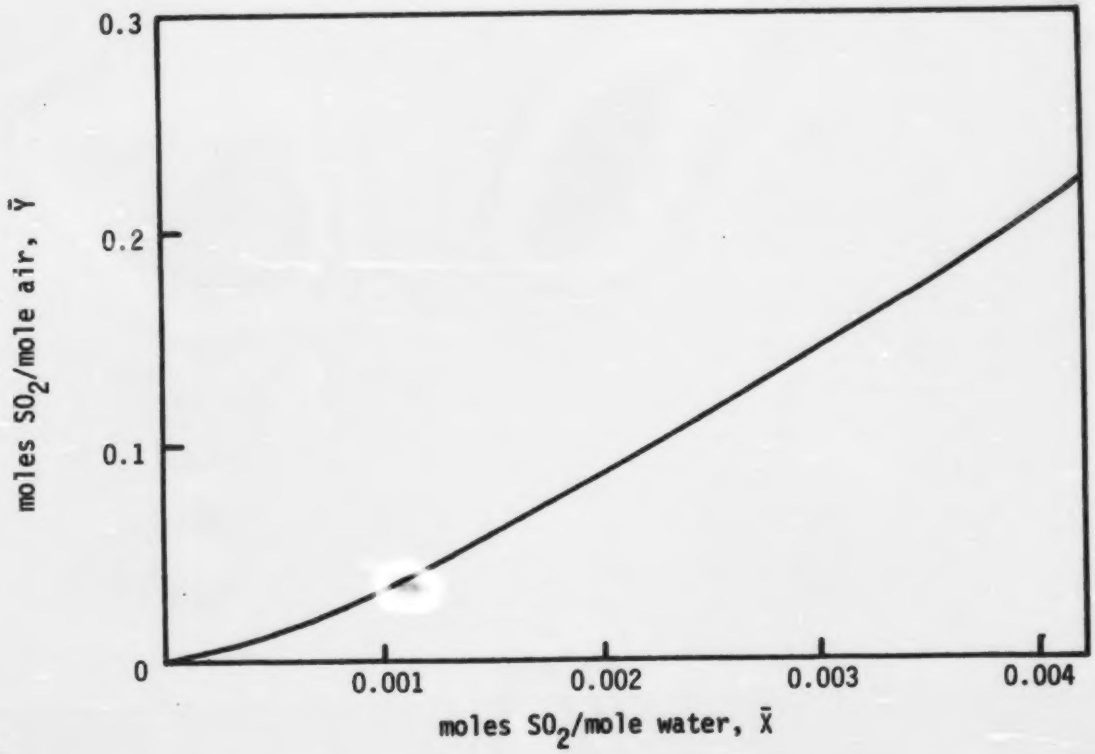

Figure B.9-3. Equilibrium curve for sulfur dioxide (SO_2)-air-water system at 90°F. (Source: Reference 1)

Note: The slope of the equilibrium curve can be determined from the following expression:

$$\frac{\bar{Y}}{(1 + \bar{Y})} = \frac{\bar{X}}{(1 + \bar{X})}$$

TABLE B.9-1. CHARACTERISTICS OF SOME TYPICAL PACKINGS (WET AND DUMP PACKED)[a]

		Nominal packing size (in.)										
Type of Packing	Material	1/4	3/8	1/2	5/8	3/4	1	1-1/4	1-1/2	2	3	3-1/2
Intalox saddles	Ceramic	F:600	330	200	-	145	98	-	52	40	22	-
		ε:0.75	-	0.78	-	0.77	0.77	-	0.81	0.79	-	-
		a:300	-	190	-	102	78	-	59.5	36	-	-
Raschig rings	Ceramic	F:1,600^{b,d}	1,000^{b,d}	640^{e}	380^{e}	225^{e}	160^{f}	125^{b,g}	95^{g}	65^{h}	37^{b,i}	-
		ε:0.73	0.68	0.63	0.68	0.73	0.73	0.74	0.71	0.74	0.78	-
		a:240	155	111	100	80	58	45	38	28	19	-
Berl saddles	Ceramic	F:900^{b}	-	240^{b}	-	170	110	-	65	45^{b}	-	-
		ε:0.60	-	0.63	-	0.66	0.69	-	0.75	0.72	-	-
		a:274	-	142	-	82	76	-	44	32	-	-
Pall rings	Plastic	F:-	-	-	97	-	52	-	32	25	-	16
		ε:-	-	-	0.88	-	0.90	-	0.905	0.91	-	-
		a:-	-	-	110	-	63	-	39	31	-	23.4
Pall rings	Metal	F:-	-	-	70	0	48	-	28	20	-	16
		ε:-	-	-	0.902	-	0.938	-	0.953	0.964	-	-
		a:-	-	-	131.2	-	66.3	-	48.1	36.6	-	-
Raschig rings 1/32-in. wall	Metal	F:700^{b}	390^{b}	300^{b}	258	185^{b}	115^{b}	-	-	-	-	-
		ε:0.69	-	0.84	-	0.88	0.92	-	-	-	-	-
		a:236	-	128	-	83.5	62.7	-	-	-	-	-
Raschig rings 1/6-in. wall	Metal	F:-	-	410	290	230	137	110^{b}	83	57	32^{b}	-
		ε:-	-	0.73	-	0.78	0.85	0.87	0.90	0.92	0.95	-
		a:-	-	118	-	71.8	56.7	49.3	41.2	31.4	20.6	-

F = Packing factor; ε = Fractional void volume, ft^3 voids/ft^3 packed volume; a = Specific packing surface, ft^2/ft^3 packed volume.

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[a] Source: Reference 1.

[b] Extrapolated

[c] 1/32-in. wall

[d] 1/16-in. wall

[e] 3/32-in. wall

[f] 1/8-in. wall

[g] 3/16-in. wall

[h] 1/4-in. wall

[i] 3/8-in. wall

TABLE B.9-2. CONSTANTS FOR USE IN DETERMINING HEIGHT OF A GAS FILM TRANSFER UNIT[a]

Packing	b	c	d	Range of 3,600 G_{area} (lb/hr-ft^2)	 L" (lb/hr-ft^2)
Raschig rings					
3/8 in.	2.32	0.45	0.47	200 to 500	500 to 1,500
1 in.	7.00	0.39	0.58	200 to 800	400 to 500
	6.41	0.32	0.51	200 to 600	500 to 4,500
1-1/2 in	17.30	0.38	0.66	200 to 700	500 to 1,500
	2.58	0.38	0.40	200 to 700	1,500 to 4,500
2 in.	3.82	0.41	0.45	200 to 800	500 to 4,500
Berl saddles					
1/2 in.	32.40	0.30	0.74	200 to 700	500 to 1,500
	0.81	0.30	0.24	200 to 700	1,500 to 4,500
1 in.	1.97	0.36	0.40	200 to 800	400 to 4,500
1-1/2	5.05	0.32	0.45	200 to 1,000	400 to 4,500
3-in. partition rings	650	0.58	1.06	150 to 900	3,000 to 10,000
Spiral rings (stacked staggered)					
3-in. single spiral	2.38	0.35	0.29	130 to 700	3,000 to 10,000
3-in. triple spiral	15.60	0.38	0.60	200 to 1,000	500 to 3,000
Drip-point grids					
No. 6146	3.91	0.37	0.39	130 to 1,000	3,000 to 6,500
No. 6295	4.56	0.17	0.27	100 to 1,000	2,000 to 11,500

[a] Source: Reference 5.

TABLE B.9-3. CONSTANTS FOR USE IN DETERMINING HEIGHT OF A LIQUID FILM TRANSFER UNIT[a]

Packing	Y	s	Range of L" (lb/hr-ft^2)
Raschig rings			
3/8 in.	0.00182	0.46	400-15,000
1/2 in.	0.00357	0.35	400-15,000
1 in.	0.0100	0.22	400-15,000
1-1/2 in.	0.0111	0.22	400-15,000
2 in.	0.0125	0.22	400-15,000
Berl saddles			
1/2 in.	0.00666	0.28	400-15,000
1 in.	0.00588	0.28	400-15,000
1-1/2 in.	0.00625	0.28	400-15,000
3-in. Partition rings (stacked, staggered)	0.0625	0.09	3,000-14,000
Spiral rings (stacked, staggered)			
3-in. single spiral	0.00909	0.28	400-15,000
3-in. triple spiral	0.0116	0.28	3,000-14,000
Drip-point grids (continuous flue)			
Style 6146	0.0154	0.23	3,500-30,000
Style 6295	0.00725	0.31	2,500-22,000

[a] Source: Reference 5.

TABLE B.9-4. SCHMIDT NUMBERS FOR GASES AND VAPORS IN AIR AT 77°F AND 1 ATM[a]

Substance	(Sc_G)[b]
Ammonia	0.66
Carbon dioxide	0.94
Hydrogen	0.22
Oxygen	0.75
Water	0.60
Carbon disulfide	1.45
Ethyl ether	1.66
Methanol	0.97
Ethyl alcohol	1.30
Propyl alcohol	1.55
Butyl alcohol	1.72
Amyl alcohol	2.21
Hexyl alcohol	2.60
Formic acid	0.97
Acetic acid	1.16
Propionic acid	1.56
i-Butyric acid	1.91
Valeric acid	2.31
i-Caproic acid	2.58
Diethyl amine	1.47
Butyl amine	1.53
Aniline	2.14
Chloro benzene	2.12
Chloro toluene	2.38
Propyl bromide	1.47
Propyl iodide	1.61
Benzene	1.76
Toluene	1.84
Xylene	2.18
Ethyl benzene	2.01
Propyl benzene	2.62
Diphenyl	2.28
n-Octane	2.58
Mesitylene	2.31

[a] Source: Reference 5.

[b] $Sc_g = \mu_G/\rho_G D_G$ where ρ_G and μ_G are the density and viscosity of the gas stream and D_G is the diffusivity of the vapor in the gas stream.

TABLE B.9-5. SCHMIDT NUMBERS FOR COMPOUNDS IN WATER AT 68°F[a]

Solute[b]	(Sc_L)[c]
Oxygen	558
Carbon dioxide	559
Nitrogen oxide	665
Ammonia	570
Bromine	840
Hydrogen	196
Nitrogen	613
Hydrogen chloride	381
Hydrogen sulfide	712
Sulfuric acid	580
Nitric acid	390
Acetylene	645
Acetic acid	1,140
Methanol	785
Ethanol	1,005
Propanol	1,150
Butanol	1,310
Allyl alcohol	1,080
Phenol	1,200
Glycerol	1,400
Pyrogallol	1,440
Hydroquinone	1,300
Urea	946
Resorcinol	1,260
Urethane	1,090
Lactose	2,340
Maltose	2,340
Mannitol	1,730
Raffinose	2,720
Sucrose	2,230
Sodium chloride	745
Sodium hydroxide	665
Carbon dioxide[d]	445
Phenol[d]	1,900
Chloroform[d]	1,230
Acetic acid[e]	479
Ethylene dichloride[e]	301

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[a] Source: Reference 5.

[b] Solvent is water except where indicated.

[c] $Sc_L = \mu_L/\rho_L D_L$ where μ_L and ρ_L are the viscosity and density the liquid and D_L is the diffusivity of the solute in the liquid.

[d] Solvent is ethanol.

[e] Solvent is benzene.

TABLE B.9-6. PRESSURE DROP CONSTANTS FOR TOWER PACKING[a]

Packing	Nominal size, (in.)	g	r	Range of L" (lb/hr-ft^2)
Raschig rings	1/2	139	0.00720	300 to 8,600
	3/4	32.90	0.00450	1,800 to 10,800
	1	32.10	0.00434	360 to 27,000
	1-1/2	12.08	0.00398	720 to 18,000
	2	11.13	0.00295	720 to 21,000
Berl saddles	1/2	60.40	0.00340	300 to 14,100
	3/4	24.10	0.00295	360 to 14,400
	1	16.01	0.00295	720 to 78,800
	1-1/2	8.01	0.00225	720 to 21,600
Intalox saddles	1	12.44	0.00277	2,520 to 14,400
	1-1/2	5.66	0.00225	2,520 to 14,400
Drip-point grid tiles	No. 6146 Continuous flue	1.045	0.00214	3,000 to 17,000
	Cross flue	1.218	0.00227	300 to 17,500
	No. 6295 Continuous flue	1.088	0.00224	850 to 12,500
	Cross flue	1.435	0.00167	900 to 12,500

[a]Source: Reference 5.

References

1. Buonicore, A. J. and L. Theodore. Industrial Control Equipment for Gaseous Pollutants. Volume I. CRC Press, Inc. Cleveland, OH. 1975.

2. Chemical Engineer's Handbook. Perry R. H. and C. H. Hilton (eds.) Fifth edition. McGraw-Hill Book Company. New York, NY. 1973.

3. U.S. EPA. Wet Scrubber System Study, Volume I: Scrubber Handbook. EPA-R2-72-118a. August 1972.

4. Vatavuk, W. M. and R. B. Neveril. Part XIII. Costs of Gas Absorbers. Chemical Engineering. October 4, 1982. pp. 135-136.

5. U.S. EPA. Organic Chemical Manufacturing, Volume 5: Adsorption, Condensation, and Absorption Devices. EPA-450/3-80-027. December 1980.

APPENDIX B.10
CONDENSER SYSTEM CALCULATIONS

Heat of Vaporization

The value for this variable can be calculated from the Clapeyron equation assuming ideal gas behavior:[1]

$$d(\ln P_{vapor})/dT = \Delta H/(RT^2) \qquad (1)$$

where:

P_{vapor} = vapor pressure, mm Hg
T = absolute temperature, °R
ΔH = heat of vaporization, Btu/lb-mole
R = universal gas constant, = 1.987 Btu/lb-mole °R

Integrating Equation 1 assuming ΔH is constant over a given temperature range leads to the following expression:

$$\ln P_{vapor} = -(\Delta H/R)(1/T) + K \qquad (2)$$

where K is a constant. By plotting ($\ln P_{vapor}$) vs (1/T) for a given compound, the value of ΔH can be determined from the slope of the line.

Using vapor pressure-temperature data from Reference 2 for styrene, the following expression is obtained through linear regression for the intervals (P_{vapor} = 1-40 mm Hg) and (T = 479-599°R):

$$\ln P_{vapor} = -8{,}780\ (1/T) + 18.3628 \qquad (3)$$

The heat of vaporization can be calculated as follows:

$$\text{Slope} = -8{,}760 = -\Delta H/R \qquad (4)$$

$$\Delta H = 8{,}760 \times 1.987 = 17{,}445 \text{ Btu/lb-mole}$$

The same procedure can be applied to any HAP.

Logarithmic Mean Temperature Difference

The expression for the logarithmic mean temperature difference is as follows:

$$\Delta T_{LM} = \left[\frac{(T_e - T_{cool,o}) - (T_{con} - T_{cool,i})}{\ln\,[(T_e - T_{cool,o}) - (T_{con} - T_{cool,i})]} \right] \qquad (5)$$

where:

T_e = emission stream temperature, ^oF
$T_{cool,o}$ = coolant outlet temperature, ^oF
T_{con} = condensation temperature, ^oF
$T_{cool,i}$ = coolant inlet temperature, ^oF

References

1. Smith, J. M. and H. C. Van Ness. Introduction To Chemical Engineering Thermodynamics. Second edition. McGraw-Hill Book Company, Inc. and Kogakusha Company, Ltd. Tokyo. 1959.

2. Chemical Engineer's Handbook. Perry R. H. and C. H. Chilton (eds.) Fifth edition. McGraw-Hill Book Company. New York, NY. 1973.

APPENDIX B.11

GAS STREAM CONDITIONING EQUIPMENT

Gas conditioning equipment includes those components that are used to temper or pretreat the gas stream to provide the most efficient and economical operation of the control device. Preconditioning equipment, installed upstream of the control device, consists of mechanical dust collectors, wet or dry gas coolers, and gas preheaters. Where the control device is a fabric filter system or electrostatic precipitator, mechanical dust collectors are required upstream if the gas stream contains significant amounts of larger particles.[1] Gas cooling devices are used to reduce the temperature of the gas stream to within the operating temperature of the filter fabric, to reduce the volume of flue gas to be treated, or to increase the HAP collection efficiency. Gas preheaters are used to increase the temperature of the gas stream to eliminate moisture condensation problems. Gas conditioning equipment is discussed below. If desired, costing of gas stream conditioning equipment can be performed by using the procedures presented in "Capital and Operating Costs of Selected Air Pollution Control Systems."[2] Design procedures for gas conditioning equipment are not included in this manual. These procedures are straightforward and readily available from vendors and common literature sources.

B.11.1 Mechanical Collectors

Mechanical dust collectors, such as cyclones, are used to remove the bulk of the heavier dust particles from the gas stream. These devices operate by separating the dust particles from the gas stream through the use of centrifugal force. The efficiency of a cyclone is determined by the entering gas velocity and diameter at the cyclone inlet. Theoretically, the higher the velocity or the smaller the inlet diameter, the greater the collection efficiency and pressure drop. Cyclones remove the majority of dust particles above 20 to 30 μm in size to reduce the loading and wear on the primary control device.[2]

In general, the particulate size distribution for the gas stream will determine the need for a cyclone collector. If the particle size distribution shows a significant amount of particulate above 20 to 30 μm then use of an upstream cyclone is necessitated for fabric filters and ESP's. "Wetted" venturi scrubbers do not generally experience operating problems in collecting large (20 to 30 μm) particles assuming correct scrubber design and operation. Use of a pretreatment mechanical dust collector may be necessary if a "nonwetted" venturi scrubber is used, since this scrubbing method requires that the liquid be free of particles that could clog the nozzles.

B.11.2 Gas Coolers

Gas coolers can be used to reduce the volume of the gas stream or to maximize the collection of HAP's by electrostatic precipitators and fabric filters. Venturi scrubbers are less sensitive to high gas stream temperatures, since the scrubber cools the gas prior to particle collection. As the temperature of an emission stream is decreased, the HAP's in vapor form will also decrease. However, care must be exercised so that the gas stream temperature does not fall below the emission stream dew point. To ensure a margin for error and process fluctuations, the emission stream temperature should fall between 50 to 100°F above its dew point. Appendix B.2 presents procedures to determine an emission stream's dew point.

Gas stream coolers can be wet or dry. Dry-type coolers operate by radiating heat to the atmosphere. Wet-type coolers (spray chambers) cool and humidify the gas by the addition of water sprays in the gas stream; the evaporating water reduces the temperature of the gas stream. A third method of cooling is through the addition of dilution air. Selection of the type of gas cooling equipment to be used is based on cost and dew point consideration. For example, a wet-type cooler would not be appropriate if cooling would increase the likelihood of condensation within the fabric filter system.

If a gas cooler is used, a recalculation of the gas stream parameters will have to be performed using standard industrial equations. For instance, if wet-type coolers are used, a new actual gas flow rate and moisture content will have to be calculated.

B.11.3 Gas Preheaters

Gas preheaters are used to increase the emission stream temperature. Condensation causes corrosion of metal surfaces, and it is of particular concern in fabric filter applications where moisture can cause plugging, or "blinding," of the fabric pores; therefore, gas preheaters can be used to elevate the temperature of an emission stream above its dew point. Methods commonly used to increase gas temperature are direct-fired afterburners, heat exchangers, and steam tracing. Afterburners are devices in which an auxiliary fuel is used to produce a flame that preheats a gas stream and that can also combust organic constituents that might otherwise blind the filter bags. Heat exchangers use a heated gas stream in a shell-and-tube type arrangement to preheat gases. With steam tracing, plants that have steam available run gas lines inside the steam lines to preheat the gases.

Emission streams containing HAP's should be preheated only to 50 to 100°F above the dew point, thus minimizing the vapor component of the HAP and enabling a baghouse or an ESP to control the HAP as effectively as possible. Appendix B.2 presents procedures to determine an emission stream's dew point.

If a gas preheater is used, a recalculation of the stream parameters will have to be performed using standard industrial equations. For example, increased gas stream temperature will increase the actual gas flow rate to be controlled.

B.11.4 References

1. Liptak, B.G. Ed. Environmental Engineers' Handbook, Volume II: Air Pollution. Chilton Book Company. Radnor, Pennsylvania. 1974.

2. U.S. EPA. Capital and Operating Costs of Selected Air Pollution Control Systems. EPA-450/5-80-002. December 1978.

APPENDIX C.1

HAP EMISSION STREAM
DATA FORM

HAP EMISSION STREAM DATA FORM*

Company ____

Location (Street) ____

(City) ____

(State, Zip) ____

Plant Contact ____

Telephone No. ____

Agency Contact ____

No. of Emission Streams Under Review ____

A. Emission Stream Number / Plant Identification ____ / ____

B. HAP Emission Source (a) ____ (b) ____ (c) ____

C. Source Classification (a) ____ (b) ____ (c) ____

D. Emission Stream HAP's (a) ____ (b) ____ (c) ____

E. HAP Class and Form (a) ____ (b) ____ (c) ____

F. HAP Content (1,2,3)** (a) ____ (b) ____ (c) ____

G. HAP Vapor Pressure (1,2) (a) ____ (b) ____ (c) ____

H. HAP Solubility (1,2) (a) ____ (b) ____ (c) ____

I. HAP Adsorptive Prop. (1,2) (a) ____ (b) ____ (c) ____

J. HAP Molecular Weight (1,2) (a) ____ (b) ____ (c) ____

K. Moisture Content (1,2,3) ____

L. Temperature (1,2,3) ____

M. Flow Rate (1,2,3) ____

N. Pressure (1,2) ____

O. Halogen / Metals (1,2) ____ / ____

P. Organic Content (1)*** ____

Q. Heat / O_2 Content (1) ____ / ____

R. Particulate Content (3) ____

S. Particle Mean Diam. (3) ____

T. Drift Velocity / SO_3 (3) ____ / ____

U. Applicable Regulation(s) ____

V. Required Control Level ____

W. Selected Control Methods ____

---

*The data presented are for an emission stream (single or combined streams) prior to entry into the selected control method(s). Use extra forms if additional space is necessary (e.g., more than three HAP's), and note this need.

**The numbers in parentheses denote what data should be supplied depending on the data in steps "C" and "E":
1 = organic vapor process emission, 2 = inorganic vapor process emission, and 3 = particulate process emission.

***Organic emission stream combustibles less HAP combustibles shown on Lines D and F.

APPENDIX C.2

CALCULATION SHEET FOR DILUTION AIR REQUIREMENTS

Dilution air flow rate:

$$Q_d = [(h_e/h_d) - 1]Q_e$$

Q_d = ________ scfm

Diluted emission stream characteristics:

$$O_{2,d} = O_2\ (h_d/h_e) + 21\ [1 - (h_d/h_e)]$$

$O_{2,d}$ = ________ %

$$M_{e,d} = M_e\ (h_d/h_e) + 2\ [1 - (h_d/h_e)]$$

$M_{e,d}$ = ________ %

$$Q_{e,d} = Q_e\ (h_e/h_d)$$

$Q_{e,d}$ = ________ scfm

Redesignate emission stream characteristics:

$O_2 = O_{2,d}$ = ________ %

$M_e = M_{e,d}$ = ________ %

$h_e = h_d$ = ________ Btu/scf

$Q_e = Q_{e,d}$ = ________ scfm

APPENDIX C.3

CALCULATION SHEET FOR THERMAL INCINERATION

4.1.1 Data Required

HAP emission stream characteristics:[a]

1. Maximum flow rate, Q_e = _________ scfm

2. Temperature, T_e = _________ _F

3. Heat content, h_e = _________ Btu/scf

4. Oxygen content,[b] O_2 = _________ %

5. Moisture content, M_e = _________ %

6. Halogenated organics: Yes _____ No _____

Required destruction efficiency, DE = _________ %

---

[a] If dilution air is added to the emission stream upon exit from the process, the data required are the resulting characteristics after dilution.

[b] The oxygen content depends on the oxygen content of the organic compounds (fixed oxygen) and the free oxygen in the emission stream. Since emission streams treated by thermal incineration are generally dilute VOC and air mixtures, the fixed oxygen in the organic compounds can be neglected.

In the case of a permit review, the following data should be supplied by the applicant:

Thermal incinerator system variables at standard conditions ($70^{o}F$, 1 atm):

1. Reported destruction efficiency, $DE_{reported}$ = _________ %

2. Temperature of emission stream entering the incinerator,
T_e = _____ ^{o}F (if no heat recovery);
T_{he} = ________ ^{o}F (if a heat exchanger is employed)

3. Combustion temperature, T_c = _________ ^{o}F

4. Residence time, t_r = _________ sec

5. Maximum emission stream flow rate, Q_e = _______ scfm

6. Excess air, ex = _________ %

7. Fuel heating value, h_f = _________ Btu/scf
(assume natural gas)

8. Supplementary heat requirement, H_f = _________ Btu/min

9. Combustion chamber volume, V_c = _________ ft^3

10. Flue gas flow rate, Q_{fg} = _________ scfm

11. Heat exchanger surface area (if a heat exchanger is employed), A = _________ ft^2

4.1.2 Pretreatment of the Emissions Stream: Dilution Air Requirements

Typically, dilution will not be required. However, if the emission stream heat content (h_e) is greater than 13 Btu/scf with oxygen concentration greater than 16 percent, see Appendix C.2 where a blank calculation sheet for determining dilution air requirements is provided.

4.1.3 Thermal Incinerator System Design Variables

Based on the required destruction efficiency (DE), select appropriate values for T_c and t_r from Table 4.1-1.

T_c = ________ °F

t_r = ________ sec

For a permit evaluation, if the applicant's values for T_c and t_r are sufficient to achieve the required DE (compare the reported values with the values presented in Table 4.1-1), proceed with the calculations. If the applicant's values for T_c and t_r are not sufficient, the applicant's design is unacceptable. The reviewer may then use the values for T_c and t_r from Table 4.1-1.

T_c = ________ °F

t_r = ________ sec

[Note: If DE is less than 98 percent, obtain information from literature and incinerator vendors to determine appropriate values for T_c and t_r.]

4.1.4 Determination of Incinerator Operating Variables

4.1.4.1 Supplementary Heat Requirements--

A. For dilute emission streams that require no additional combustion air:

a. Use Figure 4.1-2:

$$H_f = (H_f/Q_e)_{figure}\, Q_e$$

H_f = ______ Btu/min

or

b. Use Equation 4.1-1:

$$H_f = 1.1h_f\left[\frac{Q_e(1+0.002M_e)[Cp_{air}(T_c-T_r)-Cp_{air}(T_{he}-T_r)-h_e]}{h_f - 1.4\ Cp_{air}\ (T_c - T_r)}\right]$$

The values for the parameters in this equation can be determined as follows:

Q_e, h_e, M_e	Input data
h_f	Assume a value of 882 Btu/scf if no other information is available.
Cp_{air}	Use Table B.4.1-1.
T_c	Obtain value from Table 4.1-1 or from permit applicant.
T_{he}	Use the following equation if the value for T_{he} is not specified:

$T_{he} = (HR/100)\ T_c + [1 - (HR/100)]\ T_e$
where HR = heat recovery in the heat exchanger (percent). Assume a value of 50 percent for HR if no other information is available.

T_r 70°F

H_f = ________ Btu/min

If H_f is less than 5 Btu/min, redefine H_f = 5 Btu/min.

B. For emission streams that are not dilute and require additional combustion air:

a. Use Figure 4.1-3 to obtain a conservative estimate:

$$H_f = (H_f/Q_e)_{figure}\ Q_e$$

H_f = ________ Btu/min

4.1.4.2 Flue Gas Flow Rate--

A. For dilute emission streams, use Equation 4.1-2:

$$Q_{fg} = Q_e + Q_f + Q_c$$

where:

$$Q_c = 0$$

and

$$Q_f = H_f/h_f$$

Q_{fg} = ________ scfm

B. For emission streams that require additional combustion air, use the following equation to calculate Q_c (see Appendix B.4 for details):

$$Q_c = [(0.01\ H_e + 9.4\ Q_f)(1 + 0.01\ ex) - 0.0476\ O_2\ Q_e]$$

$$H_e = Q_e h_e$$

Assume ex = 18 percent if no other information is available.

Q_c = ________ scfm

Then use Equation 4.1-2 to calculate Q_{fg}:

Q_{fg} = ________ scfm

4.1.5 Combustion Chamber Volume

Use Equation 4.1-4 to Convert Q_{fg} (standard conditions) to $Q_{fg,a}$ (actual conditions):

$$Q_{fg,a} = Q_{fg}\ [(T_c + 460)/530]$$

[Note: Pressure effects are negligible.]

$Q_{fg,a}$ = ________ acfm

Use Equation 4.1-5 to calculate combustion chamber volume:

$$V_c = [(Q_{fg,a}/60)\ t_r]\ 1.05$$

Obtain value for t_r from Table 4.1-1 or from permit applicant.

V_c = ________ ft^3

If V_c is less than 36 ft^3 (minimum commercially available size),

$$V_c = 36\ ft^3$$

4.1.6 Heat Exchanger Size

A. For dilute emission streams that do not require additional combustion air:

a. Use Figure 4.1-4:

A = ________ ft^2

b. Use Equation 4.1-6:

$$A = [60\ Q_e\ (1+0.002\ M_e)Cp_{air}(T_{he}-T_e)]/U\,\Delta T_{LM}$$

The values for the parameters in this equation can be determined as follows:

Q_e, Cp_{air}, T_{he}, M_e	As specified for Equation 4.1-1.
T_e	Input data.
U	Use a value of 4 Btu/hr-ft^2-^oF unless the inquirer/applicant has provided a value.
T_c	As specified for Equation 4.1-1.
ΔT_{LM}	Calculate ΔT_{LM} using the following expression: $\Delta T_{LM} = T_c - T_{he}$ ΔT_{LM} = ________ ^oF

Heat exchanger surface area:

A = ________ ft^2

B. For emission streams that are not dilute and require additional combustion air:

a. Use Figure 4.1-5:

$$A = (A/Q_e)_{figure}\ Q_e$$

A = ________ ft^2

4.1.7 Evaluation of Permit Application

Compare the calculated values and reported values using Table 4.1-2. The combustion volume (V_c) is calculated from flue gas flow rate (Q_{fg}) and Q_{fg} is determined by emission stream flow rate (Q_e), supplementary fuel flow rate (Q_f), and combustion air requirement (Q_c). Therefore, if there are differences between the calculated and reported values for V_c and Q_{fg}, these are dependent on the differences between the calculated and reported values for Q_c and Q_f.

If the calculated and reported values are different, the differences may be due to the assumptions involved in the calculations. Discuss the details of the design and operation of the system with the applicant.

If the calculated and reported values are not different, then the design and operation of the system can be considered appropriate based on the assumptions employed in the manual.

TABLE 4.1-2. COMPARISON OF CALCULATED VALUES AND VALUES SUPPLIED BY THE PERMIT APPLICANT FOR THERMAL INCINERATION

	Calculated Value	Reported Value
Supplementary heat requirement, H_f	...	...
Supplementary fuel flow rate, Q_f	...	...
Flue gas flow rate, Q_{fg}	...	...
Combustion chamber size, V_c	...	...
Heat exchanger surface area, A	...	...

APPENDIX C.4

CALCULATION SHEET FOR CATALYTIC INCINERATION

4.2.1 Data Required

HAP emission stream characteristics:[a]

1. Maximum flow rate, Q_e = _______ scfm
2. Temperature, T_e = _______ ^oF
3. Heat content, h_e = _______ Btu/scf
4. Oxygen content[b], O_2 = _______ %
5. Moisture content, M_e = _______ %

Required destruction efficiency, DE _______ %

In the case of a permit review, the following data should be supplied by the applicant:

Catalytic incinerator system variables at standard conditions (70^oF, 1 atm):

1. Reported destruction efficiency, $DE_{reported}$ = _______ %

---

[a] If dilution air is added to the emission stream upon exit from the process, the data required are the resulting characteristics after dilution.

[b] The oxygen content depends on the oxygen content of the organic compounds (fixed oxygen) and the free oxygen in the emission stream. Since emission streams treated by catalytic incineration are generally dilute VOC and air mixtures, the fixed oxygen in the organic compounds can be neglected.

2. Temperature of emission stream entering the incinerator,

   T_e = _______ °F (if no heat recovery),

   T_{he} = _______ °F (if emission stream is preheated)

3. Temperature of flue gas leaving the catalyst bed,

   T_{co} = _______ °F

4. Temperature of combined gas stream (emission stream + supplementary fuel combustion products) entering the catalyst bed,[a]

   T_{ci} = _______ °F

5. Space velocity, SV = _______ hr^{-1}

6. Supplementary heat requirement, H_f = _______ Btu/min

7. Flow rate of combined gas stream entering the catalyst bed,

   Q_{com} = _______ scfm

8. Combustion air flow rate, Q_c = _______ scfm

9. Excess air, ex = _______ %

10. Catalyst bed requirement, V_{bed} = _______ ft^3

11. Fuel heating value, h_f = _______ Btu/scf

12. Heat exchanger surface area (if a heat exchanger is employed),

    A = _______ ft^2

4.2.2 Pretreatment of the Emission Stream: Dilution Air Requirements

For emission streams treated by catalytic incineration, dilution air typically will not be required. However, if the emission stream heat content is greater than 10 Btu/scf for air + VOC mixtures or if the emission stream heat content is greater than 15 Btu/scf for inert + VOC mixures, dilution air is necessary. For emission streams that cannot be characterized as air + VOC or inert + VOC mixtures, assume that dilution air will be required if the heat content is greater than 12 Btu/scf. In such cases, refer to Appendix C.2

---

[a] If no supplementary fuel is used, the value for this variable will be the same as that for the emission stream.

where a blank calculation sheet for determining dilution air requirements is provided.

4.2.3 Catalytic Incinerator System Design Variables

Based on the required destruction efficiency (DE), specify the appropriate ranges for T_{ci} and T_{co} and select the value for SV from Table 4.2-1.

T_{ci} (minimum) = $600^{o}F$
T_{co} (minimum) = $1,000^{o}F$
T_{co} (maximum) = $1,200^{o}F$
SV = _______ hr^{-1}

In a permit review, determine if the reported values for T_{ci}, T_{co}, and SV are appropriate to achieve the required destruction efficiency. Compare the applicant's values with the values in Table 4.2-1 and check if:

$$T_{ci} \text{ (applicant)} \geq 600^{o}F \text{ and } 1,200^{o}F \geq T_{co} \text{ (applicant)} \geq 1,000^{o}F$$

and

$$SV \text{ (applicant)} \leq SV \text{ (Table 4.2-1)}$$

If the reported values are appropriate, proceed with the calculations. Otherwise, the applicant's design is considered unacceptable. The reviewer may then wish to use the values in Table 4.2-1.

4.2.4 Determination of Incinerator Operating Parameters

4.2.4.1 Supplementary Heat Requirements--

A. For dilute emission streams that require no additional combustion air:

a. Use Equation 4.2-1 to determine if T_{ci} = $600^{o}F$ from Table 4.2-1 is sufficient to ensure an adequate overall reaction rate without damaging the catalyst, i.e., check if T_{co} falls in the interval 1,000-$1,200^{o}F$:

$T_{co} = 600 + 50\ h_e$

$T_{co} =$ _______ ^oF

If T_{co} falls in the interval 1,000-1,200^{o}F, proceed with the calculations. If T_{co} is less than 1,000^{o}F, assume T_{co} is equal to 1,000^{o}F and use Equation 4.2-2 to determine an appropriate value for T_{ci}; and then proceed with the calculations:

$T_{ci} = 1{,}000 - 50\ h_e$

$T_{ci} =$ _______ ^oF

[Note: If T_{co} is greater than 1,200^{o}F, decline in catalyst activity may occur due to exposure to high temperatures.]

b. Use Figure 4.2-2 to determine supplementary heat requirements:

$H_f = (H_f/Q_e)_{figure}\ Q_e$

$H_f =$ _______ Btu/min

c. Use Equation 4.2-3 to determine supplementary heat requirements:

$$H_f = 1.1 h_f Q_e (1+0.002M_e)\left[\frac{[Cp_{air}(T_{ci}-T_r)-Cp_{air}(T_{he}-T_r)]}{h_f - 1.4\ Cp_{air}\ (T_{ci} - T_r)}\right]$$

The values for the variables in this equation can be determined as follows:

Q_e, M_e, T_e	Input data.
h_f	Assume a value of 882 Btu/scf (for natural gas) if no other information is available.

Cp_{air}	Use Table B.4-1 in Appendix B.4.
T_{ci}	Obtain value from part (a) above or from permit applicant.
T_{he}	For no heat recovery case, $T_{he} = T_e$. For heat recovery case, use the following equation if the value for T_{he} is not specified: $T_{he} = (HR/100)T_{co} + [1 - (HR/100)]\ T_e$ where HR = heat recovery in the heat exchanger (percent). Assume a value of 50 percent for HR if no other information is available.
T_r	70°F

H_f = _______ Btu/min

B. For emission streams that are not dilute and require additional combustion air:

a. Use Figure 4.2-3 to obtain a conservative estimate:

$$H_f = (H_f/Q_e)_{figure}\ Q_e$$

H_f = _______ Btu/min

4.2.4.2 Flow Rate of Combined Gas Stream Entering the Catalyst Bed--

A. For dilute emission streams that require no additional combustion air, use Equations 4.2-4 and 5:

$$Q_{com} = Q_e + Q_f + Q_c$$

$$Q_f = H_f/h_f$$

Q_f = ________ scfm

Q_{com} = ________ scfm

B. For emission streams that require additional combustion air, use the following equation to calculate Q_c:

$$Q_c = [(0.01h_eQ_e + 9.4Q_f)(1 + 0.01ex) - 0.0476O_2Q_e]$$

Q_c = ________ scfm

Then use Equation 4.2-4 to calculate Q_{com}:

Q_{com} = ________ scfm

4.2.4.3 Flow Rate of Flue Gas Leaving the Catalyst Bed--

Use the result from the previous calculation:

$$Q_{fg} = Q_{com}$$

Q_{fg} = ________ scfm

If Q_{fg} is less than 500 scfm, define Q_{fg} as 500 scfm.

Use Equation 4.2-6 to calculate $Q_{fg,a}$:

$$Q_{fg,a} = Q_{fg}[(T_{co} + 460)/530]$$

$Q_{fg,a}$ = _______ acfm

4.2.5 Catalyst Bed Requirement

Use Equation 4.2-7:

$$V_{bed} = 60\ Q_{com}/SV$$

V_{bed} = _______ ft^3

4.2.6 Heat Exchanger Size (for Systems with Recuperative Heat Exchange Only)

A. For dilute emission streams that do not require additional combustion air:

   a. Use Figure 4.2-4 (broken line):

   $A = (A/Q_e)_{figure}\ Q_e$

   A = _______ ft^2

   b. Use Equation 4.2-8:

   $$A = [60\ Q_e\ (1+0.002M_e)Cp_{air}(T_{he}-T_e)/U\,\Delta T_{LM}]$$

   The values for the parameters in this equation can be determined as follows:

   Q_e, Cp_{air}, T_{he}, M_e, h_e — As specified for Equations 4.2-1 and 3

   T_e — Input data

U	Use a value of 4 Btu/hr-ft^2-^oF unless the inquirer/applicant has provided a value.
T_{co}	As calculated in part (a) of Step 4.2.4.1 T_{co} = _______ ^oF
ΔT_{LM}	Calculate ΔT_{LM} using the following expression: $\Delta T_{LM} = T_{co} - T_{he}$ ΔT_{LM} = _______ ^oF

Heat exchanger surface area:

A = _______ ft^2

B. For emission streams that are not dilute and require additional combustion air:
Use Figure 4.2-4 (solid line):

$$A = (A/Q_e)_{figure}\ Q_e$$

A = _______ ft^2

4.2.7 Evaluation of Permit Application

Compare the calculated values and the values supplied by the applicant using Table 4.2-2

If the calculated values for H_f, Q_c, Q_{com}, V_{bed}, and A differ from the applicant's values, the differences may be due to the assumptions involved in the calculations. Discuss the details of the design and operation of the system with the applicant.

If the calculated and reported values are not different, then the design and operation of the system can be considered appropriate based on the assumptions employed in the manual.

TABLE 4.2-2 COMPARISON OF CALCULATED VALUES AND VALUES SUPPLIED BY THE PERMIT APPLICANT FOR CATALYTIC INCINERATION

	Calculated Value	Reported Value
Supplementary heat requirement, H_f	...	...
Supplementary fuel flow rate, Q_f	...	...
Combustion air flow rate, Q_c	...	...
Combined gas stream flow rate, Q_{com}	...	...
Catalyst bed volume, V_{bed}	...	...
Heat exchanger surface area (if recuperative heat recovery is used), A	...	...

APPENDIX C.5
CALCULATION SHEET FOR FLARES

4.3.1 Data Required

HAP emission stream characteristics

1. Expected emission stream flowrate, Q_e = ____ scfm

2. Emission stream temperature, T_e = ____ ^oF

3. Heat content, h_e = ____ Btu/scf

4. Mean molecular weight of emission stream, MW_e = ____ lb/lb-mole

Flare tip diameter, D_{tip} = _____ in.
Required destruction efficiency, DE = ____ %

In the case of a permit review, the following data should be supplied by the applicant:

Flare system design parameters at standard conditions (70° F, 1 atm):

1. Flare tip diameter, D_{tip} = ____ in

2. Expected emission stream flowrate, Q_e = ____ scfm

3. Emission stream heat content, h_e = ____ Btu/scf

4. Temperature of emission stream, T_e = ____ ^{o} F

5. Mean molecular weight of emission stream, MW_e = ____ lb/lb-mole

6. Steam flowrate, Q_s = ____ lb/min

7. Flare gas exit velocity, U_{flg} = ____ ft/sec

8. Supplementary fuel flow rate,[a] Q_f = ____ scfm

9. Supplementary fuel heat content,[a] h_f = ____ Btu/scf

10. Temperature of flare gas,[b] T_{flg} = ____° F

11. Flare gas flowrate,[b] Q_{flg} = ____ scfm

12. Flare gas heat content,[b] h_{flg} = ____ Btu/scf

4.3.2 Determination of Flare Operating Variables

Based on studies conducted by EPA, relief gases having heating values less than 300 Btu/scf are not assured of achieving 98 percent destruction efficiency when they are flared in steam- or air-assisted flares.[c]

In a permit review case, if h_e is below 300 Btu/scf and no supplementary fuel is used, then the application is rejected. The reviewer may then wish to proceed with the calculations below. If h_e is equal to or above 300 Btu/scf, then the reviewer should skip to Section 4.3.2.3.

4.3.2.1 Supplementary Fuel Requirements--

For emission streams with heat contents less than 300 Btu/scf, additional fuel is required. Use Equation 4.3-1 to calculate natural gas requirements:

---

[a] This information is needed if the emission stream heat content is less than 300 Btu/scf.

[b] If no auxiliary fuel is added, the value for this variable will be the same as that for the emission stream.

[c] For unassisted flares, the lower limit is 200 Btu/scf.

$Q_f = [(300 - h_e)\ Q_e]/582$

$Q_f =$ ____ scfm

4.3.2.2 Flare Gas Flow Rate and Heat Content--

Use Equation 4.3-2 to calculate the flare gas flow rate:

$Q_{flg} = Q_e + Q_f$

$Q_{flg} =$ ____ scfm

Determine the flare gas heat content as follows:

$h_{flg} = 300$ Btu/scf if $Q_f > 0$
$h_{flg} = h_e$ if $Q_f = 0$

$h_{flg} =$ ____ Btu/scf

4.3.2.3 Flare Gas Exit Velocity--

A. Use Table 4.3-1 to calculate U_{max}:

If $300 \leq h_{flg} < 1{,}000$, use the following equation:

$U_{max} = 3.28\ [10^{(0.00118h_{flg} + 0.908)}]$

$U_{max} =$ ______ ft/sec

If $h_{flg} \geq 1{,}000$ Btu/scf, $U_{max} = 400$ ft/sec

B. Use Equation 4.3-3 to calculate U_{flg}:

$$U_{flg} = 3.06\ Q_{flg,a}/(D_{tip})^2$$

where $Q_{flg,a}$ is given by Equation 4.3-4:

$$Q_{flg,a} = [Q_{flg}\ (T_{flg} + 460)]/530$$

(see Appendix B.7 for calculating T_{flg})

$Q_{flg,a}$ = ______ acfm

U_{flg} = ______ ft/sec

C. Compare U_{flg} and U_{max}:

If $U_{flg} \leq U_{max}$, the desired destruction efficiency level of 98 percent can be achieved. [Note: U_{flg} should exceed 0.03 ft/sec for flame stability.] If $U_{flg} > U_{max}$, 98 percent destruction efficiency cannot be achieved. When evaluating a permit, reject the application in such a case.

4.3.2.4 Steam Requirements--

Assume that the amount of steam required is 0.4 lb steam/lb flare gas. Use Equation 4.3-5 to calculate Q_s:

$$Q_s = 1.03 \times 10^{-3} \times Q_{flg} \times MW_{flg}$$

See Appendix B.7 for calculating MW_{flg}.

Q_s = ____ lb/min

4.3.3 Evaluation of Permit Application

Compare the calculated and reported values using Table 4.3-2. If the calculated values of Q_f, U_{flg}, Q_{flg}, and Q_s are different from the reported values for these variables, the differences may be due to the assumptions (e.g. heating value of fuel, ratio of steam to flare gas, etc.) involved in the calculations. Discuss the details of the design and operation of the system with the applicant. If the calculated and reported values are not different, then the operation of the system can be considered appropriate based on the assumptions employed in the manual.

TABLE 4.3-2 COMPARISON OF CALCULATED VALUES AND VALUES SUPPLIED BY THE PERMIT APPLICANT FOR FLARES

	Calculated Value	Reported Value
Supplementary fuel flow rate, Q_f	. . .	. . .
Flare gas exit velocity, U_{flg}	. . .	. . .
Flare gas flow rate, Q_{flg}	. . .	. . .
Steam flow rate, Q_s	. . .	. . .

APPENDIX C.6

CALCULATION SHEET FOR CARBON ADSORPTION

4.5.1 Data Required

HAP Emission stream characteristics:

1. Maximum flow rate, Q_e = _____ scfm

2. Temperature, T_e = _____ ^oF

3. Relative humidity, R_{hum} = _____ %

4. HAP = ______

5. Maximum HAP content, HAP_e = _____ ppmv

Required removal efficiency, RE = _____ %

In the case of a permit review, the following data should be supplied by the applicant:

Carbon adsorber (fixed-bed) system variables
(standard conditions: 70^o F, 1 atm):

1. Reported removal efficiency, $RE_{reported}$ = _____ %

2. HAP content, HAP_e = _____ ppmv

3. Emission stream flow rate, Q_e = _____ scfm

4. Adsorption capacity of carbon bed,
   AC = _____ lb HAP/100 lb carbon

5. Number of beds = ____

6. Amount of carbon required, C_{req} = ____ lb

7. Cycle time for adsorption, θ_{ad} = ____ hr

8. Cycle time for regeneration, θ_{reg} = ____ hr

9. Emission stream velocity through the bed, U_e = ____ ft/min

10. Bed depth, Z_{bed} = ____ ft

11. Bed diameter, D_{bed} = ____ ft

12. Steam ratio, St = ____ lb steam/lb carbon

4.5.2 Pretreatment of the Emission Stream

4.5.2.1 Cooling--

T_e = ___ °F

If the temperature of the emission stream is significantly higher than 100°F, a heat exchanger is needed to cool it to 100°F. Refer to Appendix B.5 for the calculation procedure.

4.5.2.2 Dehumidification--

R_{hum} = ____ %

If the relative humidity level is above 50%, a condenser is required to cool and condense the water vapor in the emission stream. Refer to Section 4.7 for more details.

4.5.2.3 High VOC Concentrations--

HAP_e = _____ ppmv

If flammable vapors are present in the emission stream, VOC content will be limited to below 25% of the LEL.

LEL = _____ ppmv (from Table B.2-1)

25% of LEL = 0.25 x LEL (ppmv) = _____ ppmv

The maximum practical inlet concentration for carbon beds is about 10,000 ppmv. If HAP_e is greater than 10,000 ppmv, carbon adsorption may not be applicable.

4.5.3 Carbon Adsorption System Design Variables

Use Equation 4.5-1 to calculate the required outlet HAP concentration:

$$HAP_o = HAP_e\ (1 - 0.01\ RE)$$

HAP_o = _____ ppmv

Specify the appropriate values of θ_{ad}, θ_{reg}, and St from Table 4.5-1.

θ_{ad} = _____ hr

θ_{reg} = _____ hr

St = _____ lb steam/lb carbon

4.5.4 Determination of Carbon Adsorber System Variables

4.5.4.1 Carbon Requirements--

a. Use Equation 4.5-2:

$$C_{req} = 2 \times 1.55\ 10^{-5}\ N\theta_{ad}Q_e(HAP_e - HAP_o)\ MW_{HAP}/AC$$

Assume N = 2

Obtain MW_{HAP} from Table B.2-2 or Reference 5.
Obtain AC from Figures B.8-1, 2, 3 or Table B.8-1. If no data are available, use a conservative value of 5 lb HAP/100 lb carbon.

C_{req} = _____ lb

b. Use Figure 4.5-3 to obtain (C_{req}/Q_e):

$$C_{req} = (C_{req}/Q_e)_{figure}\ Q_e$$

C_{req} = _____ lb

4.5.4.2 Carbon Adsorber Size--

a. Use Equation 4.5-3 to calculate A_{bed}:

$$A_{bed} = Q_{e,a}/U_e$$

Calculate $Q_{e,a}$ using Equation 4.5-4:

$$Q_{e,a} = Q_e\ [(T_e + 460)/530]$$

$Q_{e,a}$ = _____ acfm

Assume $U_e = 100$ ft/sec

$A_{bed} =$ ____ ft^2

b. Use Equation 4.5-5 to calculate D_{bed}:

$D_{bed} = 1.13(A_{bed})^{0.5}$

$D_{bed} =$ ____ ft

c. Use Equation 4.5-6 to calculate volume of carbon per bed:

$V_{carbon} = (C_{req}/N)/\rho_{bed}$

Assume $\rho_{bed} = 30$ lb/ft^3

$V_{carbon} =$ ____ ft^3

d. Use Equation 4.5-7 to calculate Z_{bed}:

$Z_{bed} = V_{carbon}/A_{bed}$

$Z_{bed} =$ ____ ft

Note: If Q_e is greater than about 20,000 scfm, three or more carbon beds may need to be used.

4.5.4.3 Steam Required for Regeneration--

a. Use Equation 4.5-8 to calculate steam requirements:

$Q_s = [St \times C_{req}/(\theta_{reg} - \theta_{dry\text{-}cool})]/60$

Assume $\theta_{dry\text{-}cool}$ = 0.25 hrs.

Q_s = ____ lb/min

b. Use Figure 4.5-4:

Q_s = ____ lb/min

Calculate Q_s/A_{bed}:

Q_s/A_{bed} = ________ lb steam/min-ft^2

If Q_s/A_{bed} is greater than 4 lb steam/min-ft^2, fluidization of the carbon bed may occur.

4.5.4.4 Condenser--

a. Use Equation 4.5-10 to calculate H_{load}:

$$H_{load} = 1.1 \times 60 \times Q_s\ [\lambda + \underline{C}p_w(T_{sti} - T_{sto})]$$

Obtain λ and $\underline{C}p_w$ from Reference 6 based on the values assumed for T_{sti} and T_{sto}.

H_{load} = ___ Btu/hr

b. Use Equation 4.5-9 to calculate A_{con}:

$$A_{con} = H_{load}/U\Delta T_{LM})$$

Assume U = 150 Btu/hr-ft^2-^{o}F if no other data are available.

$$\Delta T_{LM} = \left[\frac{(T_{sti} - T_{wo}) - (T_{sto} - T_{wi})}{\ln[T_{sti} - T_{wo})/(T_{sto} - T_{wi})]}\right]$$

where $T_{wi} = 80^{o}F$ and $T_{wo} = 130^{o}F$.

ΔT_{LM} = ____ ^{o}F

A_{con} = ____ ft^2

c. Use Equations 4.5-11 and 12 to calculate Q_w:

$$Q_{cool,w} = H_{load}/[Cp_w(T_{wo} - T_{wi})]$$

$Q_{cool,w}$ = ____ lb/hr

$$Q_w = 0.002\ Q_{cool,w}$$

Q_w = ____ gal/min

4.5.4.5 Recovered Product--

Use Equation 4.5-13 to calculate Q_{rec}:

$$Q_{rec} = 1.55 \times 10^{-9} \times Q_e \times HAP_e \times RE \times MW_{HAP}$$

Q_{rec} = ____ lb/hr

4.5.5 Evaluation of Permit Application

Compare the results from the calculations and the reported values using Table 4.5-2.

If the calculated values of C_{req}, D_{bed}, Z_{bed}, Q_s, A_{con}, Q_w, and Q_{rec}, are different from the reported values, the differences may be due to the assumptions involved in the calculations. Discuss the details of the design and operation of the system with the applicant.

If the calculated values agree with the reported values, then the design and operation of the proposed carbon adsorber system may be considered appropriate based on the assumptions made in this manual.

TABLE 4.5-2 COMPARISON OF CALCULATED VALUES AND VALUES SUPPLIED BY THE PERMIT APPLICANT FOR CARBON ADSORPTION

	Calculated Value	Reported Value
Carbon requirement, C_{req}	. . .	. . .
Bed diameter, D_{bed}	. . .	. . .
Bed depth, Z_{bed}	. . .	. . .
Steam rate, Q_s	. . .	. . .
Condenser surface area, A_{con}	. . .	. . .
Cooling water rate, Q_w	. . .	. . .
Recovered product, Q_{rec}	. . .	. . .

APPENDIX C.7

CALCULATION SHEET FOR ABSORPTION

4.6.1 Data Required

1. Maximum flow rate, Q_e = _____ scfm
2. Temperature, T_e = _____ ^oF
3. HAP = _____
4. HAP concentration, HAP_e = _____ ppmv
5. Pressure, P_e = _____ mm Hg

Required removal efficiency, RE = _____ %

In the case of a permit review, the following data should be supplied by the applicant:

Absorption system variables at standard conditions (70^oF, 1 atm):

1. Reported removal efficiency, $RE_{reported}$ = _____ %
2. Emission stream flow rate, Q_e = _____ scfm
3. Temperature of emission stream, T_e = _____ ^oF
4. HAP = _____
5. HAP concentration, HAP_e = _____ ppmv
6. Solvent used = _____
7. Slope of the equilibrium curve, m = _____
8. Solvent flow rate, L_{gal} = _____ gal/min

9. Density of the emission stream, ρ_G = ____ lb/ft^3

10. Schmidt No. for the (HAP/emission stream) and (HAP/solvent) systems:

    Sc_G = ____
    Sc_L = ____
    (Refer to Appendix B.9 for definition and calculation of Sc_G and Sc_L)

11. Properties of the solvent:

    Density, ρ_L = ____ lb/ft^3
    Viscosity, μ_L = ____ centipoise

12. Type of packing used = ____

13. Packing constants:

    a = ____ b = ____ c = ____ d = ____ ϵ = ____

    Y = ____ s = ____ g = ____ r = ____

14. Column diameter, D_{column} = ____ ft

15. Tower height, (packed) Ht_{column} = ____ ft

16. Pressure drop, ΔP_{total} = ____ in H_2O

4.6.3 Determination of Absorber System Design and Operating Variables

4.6.3.1 Solvent Flow Rate--

a. Assume a value of 1.6 for AF.
Determine "m" from the equilibrium data for the HAP/solvent system under consideration (see References 1, 4, and 5 for equilibrium data).

m = ____

Use Equation 4.6-3:

Q_e = ____ scfm

$G_{mol} = 0.155\ Q_e$

G_{mol} = ____ lb-moles/hr

b. Use Equation 4.6-2:

$L_{mol} = 1.6\ m\ G_{mol}$

L_{mol} = ____ lb-moles/hr

c. Use Equation 4.6-4:

$L_{gal} = 0.036\ L_{mol}$

L_{gal} = ____ gal/min

4.6.3.2 Column Diameter--

a. Use Figure 4.6-2:
Calculate the abscissa (ABS):

$MW_{solvent}$ = ____ lb/lb-mole

$L = L_{mol} \times MW_{solvent}$

L = ____ lb/hr

MW_e = _____ lb/lb-mole

$G = G_{mol} \times MW_e$

G = _____ lb/hr

ρ_G = _____ lb/ft^3 (refer to Appendix B.9 for calculating this variable)

ρ_L = _____ lb/ft^3 (from Reference 1)

$ABS = (L/G)(\rho_G/\rho_L)^{0.5}$

ABS = _____

b. From Figure 4.6-2, determine the value of the ordinate (ORD) at flooding conditions.

ORD = _____

c. For the type of packing used, determine the packing constants from Table B.9-1:

a = _____

ϵ = _____

Determine μ_L (from Reference 1):

μ_L = _____ cp

d. Use Equation 4.6-8 to calculate $G_{area,f}$:

$$G_{area,f} = \{[ORD\ \rho_G\ \rho_L\ g_c]/[(a/\epsilon^3)(\mu_L)^{0.2}]\}^{0.5}$$

$G_{area,f}$ = ____ lb/sec-ft^2

e. Assume a value for the fraction of flooding velocity for the proposed design:

f = ____

Use Equation 4.6-9 to calculate G_{area}:

$$G_{area} = f\ G_{area,f}$$

G_{area} = ____ lb/hr-ft^2

f. Use Equation 4.6-10 to calculate the column cross-sectional area:

$$A_{column} = G/(3{,}600\ G_{area})$$

A_{column} = ____ ft^2

g. Use Equation 4.6-11 to calculate the column diameter:

$$D_{column} = 1.13\ (A_{column})^{0.5}$$

D_{column} = ____ ft

4.6.3.3 Column Height--

a. Use Equation 4.6-13 or Figure 4.6-3 to calculate N_{OG}:

Using Equation 4.6-13:

HAP_e = _____ ppmv

$HAP_o = HAP_e\ (1 - 0.01RE)$

HAP_o = _____ ppmv

$N_{OG} = \ln\{(HAP_e/HAP_o)[1 - (1/AF)] + (1/AF)\}/[1 - (1/AF)]$

N_{OG} = _____

Using Figure 4.6-3:

HAP_e/HAP_o = _____

At HAP_e/HAP_o and $1/AF = 1/1.6 = 0.63$, determine N_{OG}:

N_{OG} = _____

b. Use Equations 4.6-14, 15, and 16 to calculate H_G, H_L, and H_{OG}. Determine the packing constants in Equation 4.6-15 using Tables B.9-2 and 3.

b = _____ c = _____ d = _____

Y = _____ s = _____

Determine Sc_G and Sc_L using Tables B.9-4 and 5:

Sc_G = ____

Sc_L = ____

$L" = L/A_{column}$

L" = ____ lb/hr-ft^2

μ_L" = ____ lb/hr-ft (from Reference 1)

Calculate H_G and H_L:

$$H_G = [b(3{,}600G_{area})^c/(L")^d](Sc_G)^{0.5}$$

H_G = ____ ft

$$H_L = Y(L"/\mu_L")^s(Sc_L)^{0.5}$$

H_L = ____ ft

Calculate H_{OG} using AF = 1.6:

$$H_{OG} = H_G + (1/AF)\ H_L$$

H_{OG} = ____ ft

c. Use Equation 4.6-12 to calculate Ht_{column}:

$Ht_{column} = N_{OG}\ H_{OG}$

$Ht_{column} =$ ____ ft

d. Use Equation 4.6-18 to calculate Ht_{total}:

$Ht_{total} = Ht_{column} + 2 + (0.25\ D_{column})$

$Ht_{total} =$ ____ ft

e. Use Equation 4.6-19 to calculate Wt_{column}:

$Wt_{column} = (48\ D_{column} \times Ht_{total}) + 39(D_{column})^2$

$Wt_{column} =$ ____ lb

f. Use Equation 4.6-20 to calculate $V_{packing}$:

$V_{packing} = 0.785(D_{column})^2 \times Ht_{column}$

$V_{packing} =$ ____ ft^3

4.6.3.4 Pressure Drop Through the Column--

a. Use Equation 4.6-21 to calculate ΔP_a:

Determine the constants using Table B.9-6:

$g =$ ____

$r = \_\_\_\_$

$$\Delta P_a = g \times 10^{-8}[10^{(rL''/L)}](3{,}600\ G_{area})^2/\rho_G$$

$\Delta P_a = \_\_\_\_$ lb/ft^2-ft

b. Use Equation 4.6-22 to calculate ΔP_{total}:

$$\Delta P_{total} = \Delta P \times Ht_{column}$$

$\Delta P_{total} = \_\_\_\_$ lb/ft^2

$\Delta P_{total}(1/5.2) = \_\_\_\_$ in H_2O

4.6.4 Evaluation of Permit Application

Compare the results from the calculations and the values supplied by the permit applicant using Table 4.6-1. If the calculated values are different from the reported values, the differences may be due to the assumptions involved in the calculations. Therefore, discuss the details of the proposed design with the applicant.

If the calculated values agree with the reported values, then the design of the proposed absorber system may be considered appropriate based on the assumptions made in this manual.

TABLE 4.6-1 COMPARISON OF CALCULATED VALUES AND VALUES SUPPLIED BY THE PERMIT APPLICANT FOR ABSORPTION

	Calculated Value	Reported Value
Solvent flow rate, L_{gal}	. . .	. . .
Column diameter, D_{column}	. . .	. . .
Column height, Ht_{column}	. . .	. . .
Total column height, Ht_{total}	. . .	. . .
Packing volume, $V_{packing}$	. . .	. . .
Pressure drop, ΔP_{total}	. . .	. . .
Column weight, Wt_{column}	. . .	. . .

APPENDIX C.8

CALCULATION SHEET FOR CONDENSATION

4.7.1 Data Required

1. Maximum flow rate, Q_e = ____ scfm

2. Temperature, T_e = ____ ^oF

3. HAP = ____

4. HAP concentration, HAP_e = ____ ppmv

5. Moisture content, M_e = ____ %

6. Pressure, P_e = ____ mm Hg

Based on the control requirements for the emission stream:
Required removal efficiency, RE = ____ %

In the case of a permit review for a condenser, the following data should be supplied by the applicant:

Condenser system variables at standard conditions (70^oF, 1 atm):

1. Reported removal efficiency, $RE_{reported}$ = ____ %

2. Emission stream flow rate, Q_e = ____ scfm

3. Temperature of emission stream, T_e = ____ ^oF

4. HAP = ____

5. HAP concentration, HAP_e = ____ ppmv

6. Moisture content, M_e = ____ %

7. Temperature of condensation, T_{con} = ____ ^oF

8. Coolant used = ____

9. Temperature of inlet coolant, $T_{cool,i}$ = ____ ^oF

10. Coolant flow rate, $Q_{coolant}$ = ______ lb/hr

11. Refrigeration capacity, Ref = ____ tons

12. Condenser surface area, A_{con} = ____ ft^2

4.7.2 Pretreatment of the Emission Stream

Check to see if moisture content of the emission stream is high. If it is high, dehumidification is necessary. This can be carried out in a heat exchanger prior to the condenser.

4.7.3 Condenser System Design Variables

The key design variable is the condensation temperature. Coolant selection will be based on this temperature.

In evaluating a permit application, use Table 4.7-1 to determine if the applicant's values for T_{con}, coolant type, and $T_{cool,i}$ are appropriate:

T_{con} = ____ ^oF

Coolant type = ____

$T_{cool,i}$ = ____ ^oF

If they are appropriate, proceed with the calculations. Otherwise, reject the proposed design. The reviewer may then wish to follow the calculation procedure outlined below.

4.7.4 Determination of Condenser System Design Variables

4.7.4.1 Estimation of Condensation Temperature--

Use Equation 4.7-1 to calculate $P_{partial}$:

$$P_{partial} = 760\{(1- 0.01\ RE)/[1 - (RE \times 10^{-8}\ HAP_e)]\}HAP_e \times 10^{-6}$$

$P_{partial}$ = ______ mm Hg

Use Figure 4.7-2 to determine T_{con}:

T_{con} = ____ ^oF

4.7.4.2 Selection of Coolant--

Use Table 4.7-1 to specify the coolant (also see References 3 and 4):

Coolant = _____

4.7.4.3 Condenser Heat Load--

a. 1. Use Equation 4.7-2 to calculate $HAP_{e,m}$:

$$HAP_{e,m} = (Q_e/387)\ HAP_e \times 10^{-6}$$

$HAP_{e,m}$ = ______ lb-moles/min

2. Use Equation 4.7-3 to calculate $HAP_{o,m}$:

$$HAP_{o,m} = (Q_e/387)[1-(HAP_e \times 10^{-6})[P_{vapor}/(P_e - P_{vapor})]$$

where $P_{vapor} = P_{partial}$

$HAP_{o,m}$ = _____ lb-moles/min

3. Use Equation 4.7-4 to calculate HAP_{con}:

$$HAP_{con} = HAP_{e,m} - HAP_{o,m}$$

HAP_{con} = _____ lb-moles/min

b. 1. Calculate heat of vaporization (ΔH) of the HAP from the slope of the graph $[\ln(P_{vapor})]$ vs $[1/(T_{con} + 460)]$ for the P_{vapor} and T_{con} ranges of interest. See Appendix B.10 for details.

ΔH = _____ Btu/lb-mole

2. Use Equation 4.7-5 to calculate H_{con}:

$$H_{con} = HAP_{con}[\Delta H + \bar{C}p_{HAP} (T_e - T_{con})]$$

where $\bar{C}p_{HAP}$ can be obtained from References 3 and 4.

H_{con} = _____ Btu/min

3. Use Equation 4.7-6 to calculate H_{uncon}:

$$H_{uncon} = HAP_{o,m}\ \bar{C}p_{HAP}(T_e - T_{con})$$

H_{uncon} = ____ Btu/min

4. Use Equation 4.7-7 to calculate H_{noncon}:

$$H_{noncon} = [(Q_e/387)-HAP_{e,m}]\ \bar{C}p_{air}\ (T_e-T_{con})$$

where $\bar{C}p_{air}$ can be obtained from Table B.4-1 in Appendix B.4.

H_{noncon} = ____ Btu/min

c. 1. Use Equation 4.7-8 to calculate H_{load}:

$$H_{load} = 1.1 \times 60\ (H_{con} + H_{uncon} + H_{noncon})$$

H_{load} = ____ Btu/hr

4.7.4.4 Condenser Size--

Use Equation 4.7-9 to calculate A_{con}:

$$A_{con} = H_{load}/U\ \Delta T_{LM}$$

where ΔT_{LM} is calculated as follows:

$$\Delta T_{LM} = [(T_e-T_{cool,o}) - (T_{con}-T_{cool,i})]/\ln[(T_e-T_{cool,o})/(T_{con}-T_{cool,i})]$$

Assume: $T_{cool,i} = T_{con}-15$, and $T_{cool,o}-T_{cool,i} = 25^{o}F$

$T_{cool,i}$ = ____ ^oF

$T_{cool,o}$ = ____ ^oF

ΔT_{LM} = ____ ^oF

Assume: U = 20 Btu/hr-ft^2 -^oF (if no other estimate is available).

A_{con} = ______ ft^2

4.7.4.5 Coolant Flow Rate--

Use Equation 4.7-10 to calculate $Q_{coolant}$:

$$Q_{coolant} = H_{load}/[\underline{C}p_{coolant}\ (T_{cool,o}-T_{cool,i})]$$

The value for $\underline{C}p_{coolant}$ for different coolants can be obtained from References 3 or 4. If water is used as the coolant, $\underline{C}p_{water}$ can be taken as 1 Btu/lb-^oF.

$\underline{C}p_{coolant}$ = ___ Btu/lb-^oF

$Q_{coolant}$ = ____ lb/hr

4.7.4.6 Refrigeration Capacity--

Use Equation 4.7-11 to calculate Ref:

$$Ref = H_{load}/12{,}000$$

Ref = ____ tons

4.7.4.7 Recovered Product--

Use Equation 4.7-12 to calculate Q_{rec}:

$$Q_{rec} = 60 \times HAP_{con} \times MW_{HAP}$$

Q_{rec} = _____ lb/hr

4.7.5 Evaluation of Permit Application

Compare the results from the calculations and the values supplied by the permit applicant using Table 4.7-2. If the calculated values T_{con}, coolant type, $Q_{coolant}$, A_{con}, Ref, and Q_{rec} are different from the reported values for these variables, the differences may be due to the assumptions involved in the calculations. Discuss the details of the proposed design with the permit applicant.

If the calculated values agree with the reported values, then the design and operation of the proposed condenser system may be considered appropriate based on the assumptions made in this manual.

TABLE 4.7-2 COMPARISON OF CALCULATED VALUES AND VALUES SUPPLIED BY THE PERMIT APPLICANT FOR CONDENSATION

	Calculated Value	Reported Value
Condensation temperature, T_{con}	. . .	. . .
Coolant type	. . .	. . .
Coolant flow rate, $Q_{coolant}$	. . .	. . .
Condenser surface area, A_{con}	. . .	. . .
Refrigeration capacity, Ref	. . .	. . .
Recovered product, Q_{rec}	. . .	. . .

APPENDIX C.9
CALCULATION SHEET FOR FABRIC FILTERS

4.8.1 Data Required

HAP emission stream characteristics:

1. Flow rate, $Q_{e,a}$ = ____________ acfm
2. Moisture content, M_e = ____________ % (vol)
3. Temperature, T_e = ____________ °F
4. Particle Mean dia. = ____________ m
5. SO_3 content = ____________ ppm (vol)
6. Particulate content = ________________ grains/scf
7. HAP content = ________________ % (mass)

In the case of a permit review, the following data should be supplied by the applicant:

1. Filter fabric material ____________________
2. Cleaning method (mechanical shaking, reverse air, pulse-jet) ____________________
3. Air-to-cloth ratio ____________ ft/min
4. Baghouse construction configuration (open pressure, closed pressure, closed suction) ____________________

4.8.2 Pretreatment Considerations

If emission stream temperature is not from 50 to 100°F above the dew point, pretreatment is necessary (see Section 3.2.1 and Appendix B.2). Pretreatment will cause two of the pertinent emission stream characteristics to change; list the new values below.

1. Maximum flow rate at actual cond., $Q_{e,a}$ = __________ acfm

2. Temperature, T_e = __________ °F

4.8.3 Fabric Filter System Design Variables

1. Fabric Type(s) (use Table 4.8-1):

   a. ____________________

   b. ____________________

   c. ____________________

2. Cleaning Method(s) (Section 4.8.3.2):

   a. ____________________

   b. ____________________

3. Air-to-cloth ratio, point or range (Table 4.8-3) __________ft/min

4. Net cloth area, A_{nc}:

$$A_{nc} = Q_{e,a} / (\text{A/C ratio})$$

where: A_{nc} = net cloth area, ft^2

$Q_{e,a}$ = maximum flow rate at actual conditions, acfm

A/C ratio = air-to-cloth ratio, ft/min

A_{nc} = __________ / __________

A_{nc} = __________ ft^2

5. Gross cloth area, A_{tc}:

$$A_{tc} = A_{nc} \times \text{Factor}$$

where: A_{tc} = gross cloth area, ft_2

Factor = value from Table 4.8-4, dimensionless

A_{tc} = __________ x __________

A_{tc} = __________ ft^2

6. Baghouse configuration ____________________

4.8.4 Evaluation of Permit Application

Using Table 4.8-5, compare the results from this section and the data supplied by the permit applicant. As pointed out in the discussion on fabric filter design considerations, the basic design parameters are generally selected without the involved, analytical approach that characterizes many other control systems, such as an absorber system (Section 4.6). Therefore, in evaluating the reasonableness of any system specifications on a permit application, the reviewer's main task will be to examine each parameter in terms of its compatibility with the gas stream and particulate conditions and with the other selected parameters. The following questions should be asked:

1. Is the temperature of the emission stream entering the baghouse within 50 to 100°F above the stream dew point?
2. Is the selected fabric material compatible with the conditions of the emission stream; that is, temperature and composition (see Table 4.8-1)?
3. Is the baghouse cleaning method compatible with the selected fabric material and its construction; that is, material type and woven or felted construction (see Section 4.8.3.2 and Table 4.8-2)?
4. Will the selected cleaning mechanism provide the desired control?
5. Is the A/C ratio appropriate for the application; that is, type of dust and cleaning method used (see Table 4.8-3)?
6. Are the values provided for the gas flow rate, A/C ratio, and net cloth area consistent? The values can be checked with the following equation:

$$\text{A/C ratio} = \frac{Q_{e,a}}{A_{nc}}$$

where: A/C ratio = air-to-cloth ratio, ft/min

$Q_{e,a}$ = emission stream flow rate at actual conditions, acfm

A_{nc} = net cloth area, ft^2

7. Is the baghouse configuration appropriate; that is, is it a negative-pressure baghouse?

TABLE 4.8-5. COMPARISON OF CALCULATED VALUES AND VALUES SUPPLIED BY THE PERMIT APPLICANT FOR FABRIC FILTERS

	Calculated Value	Reported Value
Emission Stream Temp. Range[a]	. . .	. . .
Selected Fabric Material	. . .	. . .
Baghouse Cleaning Method	. . .	. . .
A/C ratio $= \frac{Q_{e,a}}{A_{nc}}$	. . .	. . .
Baghouse Configuration	. . .	. . .

[a] See Section 3.2.1.

A particular manufacturer/customer combination may employ somewhat different criteria in their selection of design parameters (such as lower annualized costs of operation at the expense of higher initial costs), and so a departure from the "rules-of-thumb" discussed here may still be compatible with achieving the needed high collection efficiencies. Further discussions with the permit applicant are recommended to evaluate the design assumptions and to reconcile any apparent discrepancies with usual practice.

APPENDIX C.10

CALCULATION SHEET FOR ELECTROSTATIC PRECIPITATORS

4.9.1 Data Required

HAP Emission Stream Characteristics:

1. Flow rate, $Q_{e,a}$ = ______________ acfm
2. Emission stream temperature, T_e = ______________ °F
3. Particulate content = ____________________________ grams/scf
4. Moisture content, M_e = ______________ % (vol)
5. HAP content = ____________________________ % (mass)
6. Drift velocity of particles, U_d = ______________ ft/s
7. Collection efficiency, CE = ______________ % mass

In case of a permit review, the following data should be supplied by the applicant. The design considerations in this section will then be used to check the applicant's design.

1. Reported collection efficiency = ________________ %
2. Reported drift velocity of particles = ______________ ft/sec
3. Reported collection plate area = ___________________ ft^2

4.9.2 Pretreatment of Emission Stream

If the emission stream temperature is not from 50 to 100°F above the dew point, pretreatment is necessary (see Section 3.2.1 and Appendix B.2). Pretreatment will cause two of the pertinent emission stream characteristics to change; list the new values below.

1. Maximum flow rate at actual cond., $Q_{e,a}$ = _____________acfm
2. Temperature, T_e = _________°F

4.9.3 ESP Design Variables

Collection plate area is a function of the emission stream flow rate, drift velocity of the particles (Table 4.9-1), and desired control efficiency. The variables are related by the Deutsch-Anderson equation:

$$A_p = \frac{-Q_{e,a}}{60 \times U_d} \times \ln(1 - CE)$$

where: A_p = collection plate area, ft^2

$Q_{e,a}$ = emission stream flow rate at actual conditions as it enters the control device, acfm

U_d = drift velocity of particles, ft/sec

CE = required collection efficiency, decimal fraction

$$A_p = \frac{(-\qquad\qquad)}{60 \times (\qquad\qquad)} \times \ln(1 - 0.\qquad)$$

A_p = ______________ ft^2

4.9.4 Evaluation of Permit Application

Using Table 4.9-2, compare the results from this section and the data supplied by the permit applicant. In evaluating the reasonableness of ESP design specifications in a permit application, the main task will be to examine each parameter in terms of its capability with the gas stream conditions.

If the applicant's collection plate area is less than the calculated area, the discrepancy will most likely be the selected drift velocity. Further discussions with the permit applicant are recommended to evaluate the design assumptions and to reconcile any apparent discrepancies.

TABLE 4.9-2. COMPARISON OF CALCULATED VALUES AND VALUES SUPPLIED BY THE PERMIT APPLICANT FOR ESP'S

	Calculated Value	Reported Value
Drift velocity of particles, U_d	...	...
Collection efficiency, CE	...	...
Collection plate area, A_p	...	...

APPENDIX C.11

CALCULATION SHEET FOR VENTURI SCRUBBERS

4.10.1 Data Required

HAP emission stream characteristics:

1. Flow rate $Q_{e,a}$ = ______________________ acfm
2. Temperature, T_e = ______________________ °F
3. Moisture content, M_e = ____________________ %
4. Required collection efficiency, CE = ______ %
5. Particle mean diameter, D_p = _________________ μm
6. Particulate content = ______________________ grains/scf
7. HAP content = ______________________% (mass)

In the case of a permit review, the following data should be supplied by the applicant:

1. Reported pressure drop across venturi = ___________"H_2O
2. An applicable performance curve for the venturi scrubber
3. Reported collection efficiency = ___________%

4.10.2 Pretreatment of Emission Stream

If the emission stream temperature is not from 50 to 100°F above the dew point, pretreatment is necessary (see Section 3.2.1 and Appendix B.2). Pretreatment will cause two of the pertinent emission stream characteristics to change; list the new values below:

1. Maximum flow rate at actual cond., $Q_{e,a}$ = ___________acfm
2. Temperature, T_e = ___________°F

4.10.3 Venturi Scrubber Design Variables

4.10.3.1 Venturi Scrubber Pressure Drop --

The pressure drop across the venturi (ΔP_v) can be estimated through the use of a venturi scrubber performance curve (Figure 4.10-2) and known values for the required collection efficiency (CE) and the particle mean diameter (D_p).

ΔP_v = ________________ in H_2O

If the estimated ΔP_v is greater than 80 in H_2O, assume that the venturi scrubber cannot achieve the desired control efficiency.

4.10.3.2 Materials of Construction --

Select the proper material of construction by contacting a vendor, or as a lesser alternative, by using Table 4.10-2.

Material of construction____________________________

4.10.4 Sizing of Venturi Scrubbers

Some performance curves and cost curves are based on the saturated gas flow rate ($Q_{e,s}$). If $Q_{e,s}$ is needed, it can be calculated as follows:

$$Q_{e,s} = Q_{e,a} \times (T_{e,s} + 460)/(T_e + 460)$$

where: $Q_{e,s}$ = saturated emission stream flow rate, acfm

$T_{e,s}$ = temperature of the saturated emission stream, °F

Use Figure 4.10-3 to determine $T_{e,s}$; the moisture content of the emission stream (M_e) must be in units of lbs H_2O/lbs dry air.

Convert M_e (% vol.) to units of lbs H_2O/lbs dry air, decimal fraction

$(M_e/100) \times (18/29)$ = ____________ lb H_2O/lb dry air

From Figure 4.10-3:

$T_{e,s}$ = __________________ °F

$Q_{e,s}$ = (   ) x (+ 460) / (+ 460)

$Q_{e,s}$ = ________________________ acfm

4.10.5 Evaluation of Permit Application

Using Table 4.10-3, compare the results of this section and the data supplied by the permit applicant. Compare the estimated ΔP_v and the reported pressure drop across the venturi, as supplied by the permit applicant.

If the estimated and reported values differ, the differences may be due to the applicant's use of another performance chart, or a discrepancy between the required and reported collection efficiencies. Discuss the details of the design and operation of the system with the applicant. If there are no differences between the estimated and reported values for ΔP_v, the design and operation of the system can be considered appropriate based on the assumptions employed in this manual.

TABLE 4.10-3. COMPARISON OF CALCULATED VALUES AND VALUES SUPPLIED BY THE PERMIT APPLICANT FOR VEMTURI SCRUBBERS

	Calculated Value	Reported Value
Particle Mean Diameter, D_p	...	...
Collection efficiency, CE	...	...
Pressure drop across venturi, ΔP_v	...	...

TABLE C.12-1. PRELIMINARY CALCULATIONS FOR CAPITAL COST ALGORITHM

(1) Calculation of Duct Diameter, D_{duct} (in.)

$$D_{duct} = 12 \left(\frac{4}{\pi} \times \frac{Q_{e,a}}{U_{duct}} \right)^{1/2}$$

where: $Q_{e,a}$ = emission stream flow rate at actual conditions, acfm

U_{duct} = velocity of gas stream in duct, ft/min

$$D_{duct} = 12 \left(\frac{4}{\pi} \times \frac{(\_\_\_\_\_\_\_\_\_\_)}{(\_\_\_\_\_\_\_\_\_\_)} \right)^{1/2} = \_\_\_\_\_\_\_\_\_\_ \text{ in.}$$

If velocity of gas stream in duct is unknown, use 2,000 ft/min; the equation then becomes:

$$D_{duct} = 0.3028\ (Q_{e,a})^{1/2}$$

$$D_{duct} = 0.3028\ (\_\_\_\_\_\_\_\_\_\_\_\_)^{1/2} = \_\_\_\_\_\_\_\_\_\_ \text{ in.}$$

(2) Calculation of Stack Diameter, D_{stack} (in.)

$$D_{stack} = 12 \left(\frac{4}{\pi} \times \frac{Q_{fg,a}}{U_{stack}} \right)^{1/2}$$

where: $Q_{fg,a}$ = actual flue gas flow rate, acfm

U_{stack} = velocity of gas in stack, ft/min

$$D_{stack} = 12 \left(\frac{4}{\pi} \times \frac{(\_\_\_\_\_\_\_\_\_\_)}{(\_\_\_\_\_\_\_\_\_\_)} \right)^{1/2} = \_\_\_\_\_\_\_\_\_\_ \text{ in.}$$

The gas stream velocity in the stack should be at least 4,000 ft/min. If velocity is unknown, use 4,000 ft/min; the equation then becomes:

$$D_{stack} = 0.2141\ (Q_{fg,a})^{1/2}$$

$$D_{stack} = 0.2141\ (\_\_\_\_\_\_\_\_\_\_\_\_)^{1/2} = \_\_\_\_\_\_\_\_\_\_ \text{ in.}$$

(3) Calculation of Total System Pressure Drop, ΔP_t (in. H_2O)

$$\Delta P_t = \Delta P_{duct} + \Delta P_{stack} + \Delta P_{device\ \#1} + \Delta P_{device\ \#2} + \Delta P_{device\ \#3}$$

[Note: See Table 5-7 (p. 5-44) for ΔP values.]

$$\Delta P_t = \_\_\_\_\_ + \_\_\_\_\_ + \_\_\_\_\_ + \_\_\_\_\_ + \_\_\_\_\_ = \_\_\_\_\_ \text{ in. } H_2O$$

TABLE C.12-2. ESTIMATE OF CAPITAL COSTS IN CURRENT DOLLARS

COST ELEMENTS	FIGURE OR TABLE COST		ESCALATION FACTOR (Current FE/Base FE) see Table 5-2, p. 5-39		CURRENT COST
1. Major Equip. Pur. Cost					
Thermal Incinerator[a]	\$________	x	(____ / ____)	=	\$________
Heat Exchanger[b]	\$________	x	(____ / ____)	=	\$________
Catalytic Incinerator[c]	\$________	x	(____ / ____)	=	\$________
Catalyst[c], V_{cat} =	____ ft^3 x ____ \$/ft^3	x	(____ / ____)	=	\$________
Carbon Adsorber[d]	\$________	x	(____ / ____)	=	\$________
Carbon[d], C_{req} =	____ lb x ____ \$/lb	x	(____ / ____)	=	\$________
Absorber[e]	\$________	x	(____ / ____)	=	\$________
Platforms and Ladders[e]	\$________	x	(____ / ____)	=	\$________
Packing[e], V_{pack} =	____ ft^3 x ____ \$/ft^3	x	(____ / ____)	=	\$________
Condenser[f]	\$________	x	(____ / ____)	=	\$________
Refrigerant[f]	\$________	x	(____ / ____)	=	\$________
Fabric Filter[g]	\$________	x	(____ / ____)	=	\$________
Bags[g], A_{tc} =	____ ft^2 x ____ \$/ft^2	x	(____ / ____)	=	\$________
ESP[h]	\$________	x	(____ / ____)	=	\$________
Venturi Scrubber[i]	\$________	x	(____ / ____)	x	
Design Factors[i]	________ (Thickness Factor)	x	________ (Composition Factor)	=	\$________
			SUBTOTAL		\$________

(continued)

TABLE C.12-2. ESTIMATE OF CAPITAL COSTS IN CURRENT DOLLARS
(Concluded)

COST ELEMENTS	FIGURE OR TABLE COST	ESCALATION FACTOR (Current FE/Base FE) see Table 5-2, p. 5-39	CURRENT COST
2. Aux. Equip. Purch. Cost			
Ductwork[j]	\$_____ x _____ (Length)	x (_____ / _____)	= \$_____
Fan[k]	\$_____	x (_____ / _____)	= \$_____
Motor[l]	\$_____ (Fan Current Cost)	x 0.15	= \$_____
Stack[m]	\$_____	x (_____ / _____)	= \$_____
		SUBTOTAL	\$_____
3. Pre-Total Purch. Equip. Cost	Item 1 Subtotal + Item 2 Subtotal		\$_____
Adjustments[n]	(Item 3) x -0.091		\$_____
4. TOTAL Purc. Equip. Cost	Item 3 + Adjustments		\$_____
5. Instrumentatiun and Controls	10% of Item 4		\$_____
6. Freight and Taxes	8% of Item 4		\$_____
7. TOTAL Purchased Cost	Item 4 + Item 5 + Item 6		\$_____
8. TOTAL CAPITAL COSTS	F^{o} x (Item 7); where F = _____		\$_____

FOOTNOTES TO TABLE C.12-2

[a] Thermal Incinerator: Figure 5-1 (p. 5-19), includes fan plus instrumentation and control costs for thermal incinerators, in addition to the major equipment purchased cost. Additional auxiliary equipment (ductwork and stack) purchased costs and costs of freight and taxes must be added to obtain the total purchased cost.

[b] Heat Exchangers: If the HAP control system requires a heat exchanger, obtain the cost from Figure 5-2 (p. 5-20), escalate this cost using the appropriate factor, and add to the major equipment purchased cost.

[c] Catalytic Incinerator: Figure 5-3 (p. 5-21) provides the cost of a catalytic incinerator, less catalyst costs. The "TABLE" catalyst cost is estimated by multiplying the volume of catalyst required (V_{cat}, p. 4.2-16) by the catalyst cost factor ($\$/ft^3$) found on Table 5-3 (p. 5-40). Catalyst costs, all auxiliary equipment (ductwork, fan, and stack) purchased costs and the cost of instrumentation and controls, and freight and taxes must be added to obtain the total purchased cost.

[d] Carbon adsorber: Figure 5-4 (p. 5-22) (packaged carbon adsorber systems) includes the cost of carbon, beds, fan and motor, instrumentation and controls, and a steam regenerator. Additional auxiliary equipment (ductwork and stack) purchased costs and costs of freight and taxes must be added to obtain the total purchased cost. Figure 5-5 (p. 5-23) (custom carbon adsorber systems) includes beds, instrumentation and controls, and a steam regenerator, less carbon. The "TABLE" carbon cost for custom carbon adsorbers is estimated by multiplying the weight of carbon required (C_{req}, p. 4.5-10) by the carbon cost factor ($/lb) found on Table 5-3 (p. 5-40). Costs of carbon, all auxiliary equipment (duct, fan, stack) purchased costs, and freight and taxes must be added to obtain the total purchased cost.

[e] Absorber: Figure 5-6 (p. 5-24) does not include the cost of packing, platforms, and ladders. The cost of platforms and ladders (Fig. 5-7 p. 5-25) and packing must be added to obtain the major purchased equipment cost. The "TABLE" packing cost is estimated by multiplying the volume of packing required (V_{pack}, p. 4.6-16) by the appropriate packing cost factor found on Table 5-4 (p. 5-41). All auxiliary equipment (ductwork, fan, and stack) purchased costs, and costs of freight and taxes must be added to obtain the total purchased cost.

[f] Condenser Systems: Figure 5-8 (p. 5-26) yields total capital costs for cold water condenser systems. For systems needing refrigerant, the applicable cost from Figure 5-9 (p. 5-27) must be added to obtain the total capital costs. In either case, the escalated cost estimate is then placed on Line 8, "TOTAL CAPITAL COSTS."

[g] Fabric Filter Systems: Figure 5-10 (p. 5-28) gives the cost of a negative pressure, insulated baghouse. The curve does not include bag costs. The "TABLE" bag cost is estimated by multiplying the gross cloth area required (A_{tc}, p. 4.8-14) by the appropriate bag cost factor found on Table 5-5 (p. 5-42). Bag costs, all auxiliary equipment (duct, fan, and stack) purchased costs, the cost of instrumentation and controls, and freight and taxes must be added to obtain the total purchased cost.

FOOTNOTES TO TABLE C.12-2 (Concluded)

[h] Electrostatic Precipitators: Figure 5-11 (p. 5-29) provides the cost for an insulated ESP. All auxiliary equipment (duct, fan, and stack) purchased costs, the cost of instrumentation and controls, and freight and taxes must be added to obtain the total purchased cost.

[i] Venturi Scrubber: Figure 5-12 (p. 5-30) includes the cost of instrumentation and controls in addition to the major equipment purchased cost. This cost curve is based on a venturi scrubber constructed from 1/8-inch carbon steel. Figure 5-13 (p. 5-31) is used to determine if 1/8-inch steel is appropriate for a given application (use the higher curve). If thicker steel is required, Figure 5-14 (p. 5-32) yields an adjustment factor for various steel thicknesses; this factor is used to escalate the cost obtained from Figure 5-12. In addition, if stainless steel is required (see Section 4.10.3.2) multiply the scrubber cost estimate by 2.3 for 304L stainless steel or by 3.2 for 316L stainless steel. Costs of all auxiliary equipment (ductwork, fan, and stack) and freight and taxes must be added to obtain the total purchased cost.

[j] Ductwork: Figure 5-15 (p. 5-33) gives the cost of straight ductwork made of carbon steel for various thicknesses, based on the required duct diameter. Figure 5-16 (p. 5-34) gives the cost of straight ductwork made of stainless steel for various thicknesses, based on the required duct diameter. Preliminary calculations (duct diameter, see Table C.12-1) are necessary to estimate ductwork costs.

[k] Fan: Figure 5-17 (p. 5-35) gives the cost of a fan based on the gas flow rate at actual conditions and the HAP control system pressure drop (in inches of H_2O). The applicable fan class is also based on the HAP control system pressure drop. Calculation of the total system pressure drop is presented in Table C.12-1.

[l] The cost of a motor is estimated as 15% of the fan cost.

[m] Stack: Figure 5-18 (p. 5-36) gives the cost of a carbon steel stack at various stack heights and diameters. Figure 5-19 (p. 5-37) gives the price of a stainless steel stack at various stack heights and diameters. Preliminary calculations (stack diameter, see Table C.12-1) are necessary to estimate stack costs. For both figures, use the curve that best represents the calculated diameter.

[n] For thermal incinerators, carbon adsorbers, and venturi scrubbers, the purchase cost curve includes the cost for instrumentation and controls. This cost (i.e., the "Adjustment") must be subtracted out to estimate the total purchased equipment cost. This is done by adding the Item 1 subtotal and the Item 2 subtotal and multiplying the result by -0.091. This value is added to the preliminary total purchased equipment cost to obtain the total purchased equipment cost. For all other major equipment, the "Adjustment" equals zero.

[o] Obtain factor "F" from "TOTAL" line in Table 5-8 (p. 5-45).

TABLE C.12-3. PRELIMINARY CALCULATIONS FOR ANNUALIZED COST ALGORITHM

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(1) Calculation of Annual Elect. Requirement, AER (Line 5, Table C.12-6)

a. Fan Electricity Requirement, FER

FER = 0.0002 ($Q_{fg,a}$) x ΔP x HRS

where: $Q_{fg,a}$ = actual flue gas flow rate, acfm

ΔP = total HAP control system pressure drop, in. H_2O (see Table 5-7, p. 5-44)

HRS = annual operating hours, hr [Note: Use 8,600 unless otherwise specified.]

FER = 0.0002 (__________) x _____ x _______ = ___________ kWh

b. Baghouse Electricity Requirement, BER

[Note: Assume 0.0002 kW are required per ft^2 of gross cloth area.]

BER = 0.0002 (A_{tc}) x HRS

where: A_{tc} = gross cloth area required, ft^2 (p. 4.8-14)

BER = 0.0002 (______________) x ________ = ___________ kWh

c. ESP Electricity Requirement, EER

[Note: Assume 0.0015 kW are required per ft^2 of collection area.]

EER = 0.0015 (A_p) x HRS

where: A_p = collection plate area, ft^2 (p. 4.9-4)

EER = 0.0015 (__________) x ___________ = ___________ kWh

d. Annual Electricity Requirement, AER

AER = FER + BER + EER

AER = ________ + ________ + ________ = ____________ kWh

(continued)

TABLE C.12-3. PRELIMINARY CALCULATIONS FOR ANNUALIZED COST ALGORITHM (concluded)

(2) Calculation of Capital Recovery Factor, CRF (Line 18, Table C.12-6)

$\mathrm{CRF} = [i(1 + i)^{n}] / [(1 + i)^{n} - 1]$

where: i = interest rate on borrowed capital, decimal fraction
[Note: Unless otherwise specified use 10 percent.]

n = control device lifetime, years (see Table 5-12, p. 5-50)

$\mathrm{CRF} = [\_\_\_\_ \times (1 + \_\_\_\_)^{(\quad)}] / [(1 + \_\_\_\_)^{(\quad)} - 1] = \_\_\_\_\_\_$

(3) Calculation of Annual Operator Labor, OL (Line 9, Table C.12-6)

OL = (HRS) (operator hours per shift) / (operating hours per shift)
[Note: Obtain operator hr/shift value from Table 5-12, p. 5-50.]

OL = (__________) x (__________) / (____) = ________ hr

(4) Calculation of Annual Maintenance Labor, ML (Line 11, Table C.12-6)

ML = (HRS) (maintenance hours per shift) / (operating hours per shift)
[Note: Obtain maintenance hr/shift value from Table 5-12, p. 5-50.]

ML = (__________) x (__________) / (____) = ________ hr

TABLE C.12-4. ADDITIONAL UTILITY REQUIREMENTS

(1) Fuel Requirement for Incinerators (Line 1 or Line 2, Table C.12-6)

[Note: The design sections for thermal and catalytic incinerators are developed under the assumption that natural gas is used as the supplementary fuel. Fuel oil could be used, however, the use of natural gas is normal industry practice. If fuel oil is used, the equation below can be used by replacing Q_f with the fuel oil flow rate in units of gallons per minute. The resultant product of the equation (gallons of fuel oil required) is then used on Line 2 of Table C.12-6.]

Fuel Requirement = 60 (Q_f) x HRS

where: Q_f = supplementary fuel required, scfm (p. 4.1-11 or p. 4.2-13)

HRS = annual operating hours, hr
[Note: Use 8,600 hours unless otherwise specified.]

Fuel Requirement = 60 (__________) x________ = ____________ ft^3

(2) Steam Requirement for Carbon Adsorber (Line 4, Table C.12-6)

[Note: Assume 4 lb of steam required for each lb of recovered product.]

Steam Requirement = 4 (Q_{rec}) x HRS

where: Q_{rec} = quantity of HAP recovered, lb/hr (p. 4.5-20)

HRS = annual operating hours, hr
[Note: Use 8,600 hours unless otherwise specified.]

Steam Requirement = 4 (__________) x ________ = ____________ lb

(3) Cooling Water Requirement for Carbon Adsorber (Line 3, Table C.12-6)

[Note: Assume 12 gal of cooling water required per 100 lbs steam.]

Water Requirement = 0.48 (Q_{rec}) x HRS

where: Q_{rec} = quantity of HAP recovered, lb/hr (p. 4.5-20)

HRS = annual operating hours, hr
[Note: Use 8,600 hours unless otherwise specified.]

Water Requirement = 0.48 (__________) x ________ = ____________ gal

(continued)

TABLE C.12-4. ADDITIONAL UTILITY COSTS (concluded)

(4) Absorbent Requirement for Absorbers (Line 3 or 6, Table C.12-6)

[Note: Assume no recycle of absorbing fluid (water or solvent).]

Absorbent Requirement = 60 (L_{gal}) x HRS

where: L_{gal} = absorbing fluid flow rate, gal/min (p. 4.6-7)

HRS = annual operating hours, hr
[Note: Use 8,600 hours unless otherwise specified.]

Absorbent Requirement = 60 (__________) x _______ = ________ gal

(5) Water Requirement for Venturi Scrubbers (Line 3, Table C.12-6)

[Note: Assume 0.01 gal of water required per acf of emission stream.]

Water Requirement = 0.6 ($Q_{e,a}$) x HRS

where: $Q_{e,a}$ = emission stream flow rate into scrubber, acfm

HRS = annual operating hours, hr
[Note: Use 8,600 hours unless otherwise specified.]

Water Requirement = 0.6 (__________) x _______ = __________ gal

TABLE C.12-5. ESTIMATION OF REPLACEMENT PARTS ANNUALIZED COSTS

(1) Annualized Catalyst Replacement Costs (Line 7, Table C.12-6)

Over the lifetime of a catalytic incinerator, the catalyst is depleted and must be replaced (assume catalyst lifetime is 3 years):

Annual Catalyst Cost = (Catalyst Current Cost[a]) / 3

Annual Catalyst Cost = (________________) / 3 = $________________

(2) Annualized Carbon Replacement Costs (Line 7, Table C.12-6)

Over the lifetime of a carbon adsorber, the carbon is depleted and must be replaced (assume carbon lifetime is 5 years):

Annual Carbon Cost = (Carbon Current Cost[a]) / 5

Annual Carbon Cost = (________________) / 5 = $________________

(3) Annualized Refrigerant Replacement Costs

Refrigerant in a condenser needs to be replaced periodically due to system leaks; however, the loss rate is typically very low. Therefore, assume the cost of refrigerant replacement is negligible.

(4) Annualized Bag Replacement Costs (Line 7, Table C.12-6)

Over the lifetime of a fabric filter system the bags become worn and must be replaced (assume bag lifetime is 2 years):

Annual Bag Cost = (Bag Current Cost[a]) / 2

Annual Bag Cost = (________________) / 2 = $________________

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[a] See Table C.12-2.

TABLE C.12-6. ESTIMATE OF ANNUALIZED COSTS IN CURRENT DOLLARS

COST ELEMENTS	UNIT COSTS/FACTOR	ANNUAL EXPENDITURE	CURRENT DOLLARS
Direct Operating Costs			
1. Natural Gas[a]	\$0.00425 per ft^3	x ________ ft^3 =	\$________
2. Fuel Oil[a]	\$1.025 per gal	x ________ gal =	\$________
3. Water[a]	\$0.0003 per gal	x ________ gal =	\$________
4. Steam[a]	\$0.00504 per lb	x ________ lb =	\$________
5. Electricity[b]	\$0.059 per kWh	x ________ kWh =	\$________
6 Solvent[a]	\$______ per gal[c]	x ________ gal =	\$________
7. Replacement Parts	As applicable (see Table C.12-5)		\$________
8. Replacement Labor	100% of Line 7		\$________
9. Operator Labor[b]	\$11.53 per hr	x ______ hr =	\$________
10. Supervision Labor	15% of Line 9		\$________
11. Maintenance Labor[b]	\$11.53 per hr	x ______ hr =	\$________
12. Maintenance Materials	100% of Line 11		\$________
13. SUBTOTAL	Add Items 1 through 12		\$________
Indirect Operating Costs			
14. Overhead	80% of Sum of Lines 8, 9, 10, and 11		\$________
15. Property Tax	1% of Total Capital Cost[d]		\$________
16. Insurance	1% of Total Capital Cost[d]		\$________
17. Administration	2% of Total Capital Cost[d]		\$________
18. Capital Recovery[b]	(CRF) x Total Capital Cost[d]; where CRF = ______		\$________
19. SUBTOTAL	Add Items 14 through 18		\$________
20. CREDITS	As applicable (see Section 5.2.3)		\$________
NET ANNUALIZED COSTS	Item 13 + Item 19 - Item 20		\$________

[a] See Table C.12-4. [b] See Table C.12-3. [c] As applicable. [d] Total Capital Cost from Line 8 of Table C.12-2.